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Edited by
J. Als-Nielsen and B. Lebech

Risø National Laboratory, DK-4000 Roskilde, Denmark
March 1984

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PHYSICS DEPARTMENT ANNUAL PROGRESS REPORT

1 January - 31 December 1983

edited by J. Als-Nielsen and B. Lebech

Abstract. Research in the Physics Department at Risø National Laboratory covers three main fields: Condensed Matter Physics, Plasma Physics and Meteorology. The report is a progress report describing the principal activities in these fields for the period from 1 January to 31 December 1983.
The condensed matters physics research is predominantly experimental utilising diffraction of neutrons and x-rays. The research topics range from studies of structure, excitations and phase transitions in model systems to studies of ion transport, texture and recrystallization kinetics with a more applied nature.
The plasma physics research is partly experimental and partly theoretical. A study of pellet-plasma interaction is of applied nature and aimed at assessing the possibilities of refuelling a fusion reactor by shooting deuterium-tritium pellets into the plasma. A study of the fundamental physics of plasmas deals with investigations of wave propagation properties, instabilities, solitons, turbulence, etc.
The research and applied work within meteorology lies within micrometeorology and the subjects range from surface energy balance studies, over studies of the general structure of atmospheric coherence and boundary layer response to change in surface elevation, to specific studies of turbulent dispersion and deposition of airborne material. As part of the applied work within meteorology and wind energy, the test station for small windmills tests and licences windmills for the Danish market and offers consulting assistance for the Danish windmill manufacturers.

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PREFACE

Research in the Physics Department covers three main fields:

Condensed matter physics
Plasma physics
Metereology

The principal activities in these fields are presented in the first three chapters of this Progress Report covering the period from 1 January to 31 December 1983. The condensed matters physics research is predominantly experimental utilising diffraction of neutrons and x-rays. The research topics range from studies of structure, excitations and phase transitions in model systems to studies of ion transport, texture and recrystallization kinetics with a more applied nature.
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Jens Als-Nielsen

Head of Physics Department

1. CONDENSED MATTER PHYSICS

1.1. Introduction to work in condensed matter physics

The condensed matters physics research is predominantly experimental utilising diffraction of neutrons and x-rays. The neutron scattering experiments are carried out at the DR3 reactor, where the physics department operates seven spectrometers, including a new small angle scattering facility which was commissioned last year. The experiments using synchrotron x-ray radiation take place at HASY-laboratory, at DESY in Hamburg. The research topics range from studies of structure, excitations and phase transitions in model systems to studies of ion transport, texture and recrystallication kinetics with a more applied scope. A major part of the neutron scattering work concerns magnetic materials utilizing the unique properties of the neutron as a probe for magnetism and the theoretical efforts are also centred in this field. The synchrotron and x-ray research has dealt with structures of the liquid-vapor interface of liquid crystals and monolayers on surfaces as well as technical developments.
The small angle neutron scattering spectrometer is partly operated as a user-facility available to visiting scientists for structural studies in molecular biology. Otherwise it is used like other spectrometers for in-house, often collaborative, programs for studies of radiation damage, composite and porous materials, and polymers.

1.1.1. Correlation theory of Heisenberg ferro and antiferromagnets in an applied field

The linear antiferromagnet in an applied field was discussed in considerable detail by Lovesey and Loveluck using the Mori theory. In this approach the dynamical variables are usually taken to be the operators (and derivatives thereof) which in the hydrodynamic limit satisfy conservation laws. For the antiferromagnet these variables are the magnetization density M_q and the energy density E_q. A coupling between these should occur for finite external fields. Clearly this basis is designed to treat the long wavelength limit $q \to 0$ and $\omega \to 0$. However, this limit is not easily observable by either neutron scattering or in numerical simulation studies. In the correlation theory an alternative set of dynamical variables is chosen; namely dynamical variables, which allows the local or short range properties to be calculated exactly. This provides a description of the normal modes at high q and ω. This basis turns out to be the same as is convenient for the description of the ordered phase for $T < T_N$. Consequently all temperatures can be treated in the same framework. The correlation theory does not use the hydrodynamic concept energy modes, but gives a rather simple picture of the dynamics determined by spin fluctuations on different sublattices. As a result the renormalization and damping of the spin wave modes are calcualted and in addition the characteristica of a central peak, which was not previously discussed.

Author: (7)

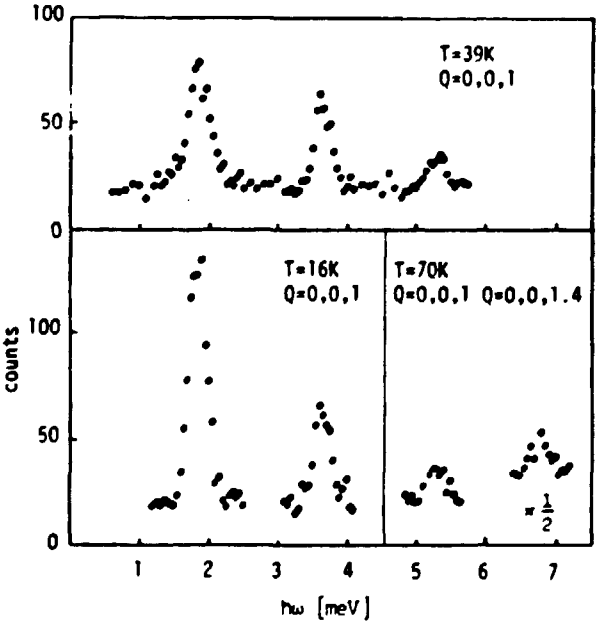
1.1.2. Excitations in an incommensurate sinusoidal groundstate

The problem of finding the excitation spectrum for a linear chain with an incommensurately varying potential is similar to that for a randomly disordered system. One finds localized states, band gaps and low frequency excitations. Using the transfer-matrix theory and a direct numerical approach the excitation spectrum was discussed.

Authors: (100,7)

1.1.3. Biquadratic exchange in $CsMn_xMg_{1-x}Br_3$

The spin wave spectrum in a normal antiferromagnet with long range order does not allow for a separation of the bilinear and the biquadratic exchange terms. This can be done by studying the excitations in a diluted 1-D system where the magnetic ions form small clusters. The magnetic excitations of Mn^{2+} pairs in $CsMn_{0.28}Mg_{0.72}Br_3$ have been studied by inelastic neutron scattering. The energy spectra shows four well resolved peaks with non-uniform energy spacings between them (see figure). The non-uniform spacings are evidence of the presence of biquadratic exchange. The equation of motion has been solved for a Hamiltonian including bilinear and biquadratic exchange terms. The resulting energy-momentum relation for antiferromagnetic spin waves is calculated using the coupling parameters determined from the pair spectra and is found to agree with the experimental data for $CsMnBr_3$.



Authors: (5,45,48)

1.1.4. Field dependence of the excitations in the singlet ground-state system $Cs_3Cr_2Br_9$

The study of the novel singlet ground-state system $Cs_3Cr_2Br_9$ has been continued with neutron scattering measurements of the field dependence of the low energy magnetic excitations. The singlet ground-state nature arises from the crystallographic pairing of the Cr^{+3}-ions in the lattice with a triplet excited state. The coupling between the magnetic pair causes strong dispersion of the excitations. The applied field lifts the degeneracy of the triply degenerated mode and this results in an almost linear Zeeman splitting which drives the lowest energy towards zero at H_c = 2.5 T. However, contrary to expectations based on RPA calculations, we do not observe long range order for $H>H_c$ at T = 1.4 K, well below the calculated ordering temperature of 3.2 K. The lack of long range order may be due to the features of the system which makes it analogous to the 2-D x-y model where fluctuations prevent the appearance of normal long range order at finite temperature. Further experiments are planned to explore this analogy.

Authors: (29,5,70,52)

1.1.5. Random field effects in the antiferromagnet $K_2Ni_{1-x}Zn_xF_4$

A uniform magnetic field applied to a diluted antiferromagnet gives rise to a random staggered field which may destroy the long range order*. In $K_2Ni_{1-x}Zn_xF_4$ the effect is particularly dramatic for the 3-D ordering along the c-axis and it is seen even at small fields ($\sim$ 0.1 T) and low concentrations (x = 0.1). Neutron scattering has been used to study both the in-plane and the out-of-plane correlations in fields up to 9.5 T, for x = 0.1, 0.2 and 0.3 in the temperature range 4.2 K to 90 K. The out-of-plane domain structure is excellently described by a simple exponential correlation function, $g(z) \propto e^{-\kappa z}$ and the field dependence of the correlation length $\xi = \kappa^{-1}$ is given by a power law $\xi \propto H^{-\nu}$. The preliminary analysis yields ν = 0.7 ($0 < H < 0.5$ T) at the lowest concentrations. The in-plane correlations have much longer range and they can only be resolved at the highest fields. The fits to resolution convoluted line shapes show that the data is well-described by the form

$$S_+(q) = \frac{\kappa}{(q^2+\kappa^2)^{3/2}},$$

but the analysis is not yet completed.

*Birgeneau, R.J., Yoshizawa, H., Cowley, R.A., Shirane, G. and Ikeda, H. (1983). Phys. Rev. B28, 1438.

Authors: (42,34,41,5)

1.1.6. Magnetic ordering in the semimagnetic-semiconductor $Cd_{1-x}Mn_xTe$

The diluted magnetic semiconductor $Cd_{1-x}Mn_xTe$ shows magnetic properties which are of antiferromagnetic nature for $0.60 < x < 0.71$. In this range of compositions, neutron diffraction studies show a strong tendency towards type III antiferromagnetic ordering at low temperatures. The observed magnetic peaks remain Lorentzian down to 5 K although susceptibility data suggests an ordering temperature of 46 K ($x = 0.65$). This indicates that true long range order never develops in this system. Indeed, the magnetic ordering temperature determined by neutron scattering is considerably higher than the transition temperature determined from the susceptibility data, and even at ~ 90 K pronounced elastic scattering is observed. We have modelled the system by a Monte Carlo computer simulation. The model system is a cube of 4000 fcc sites (10×10×10 unit cells) with periodic boundary conditions. The sites are populated randomly by classical spins and the spin energy is calculated in the Heisenberg model assuming only nearest and next nearest exchange interactions. Several physical quantities which could be compared with experimental data were calculated. The model reproduced correctly the positions of the peaks corresponding to the short range antiferromagnetic ordering observed in the real system and simulated satisfactorily the temperature dependence of the intensity, the width and shape of observed magnetic peaks.

Authors: (6,94,50,49)

1.1.7. Neutron diffraction study of MnAs under high pressure

At 4.2 K and ambient pressure, MnAs has been found to be ferromagnetic with the moments lying mainly in the basal plane of the NiAs-type structure. Upon heating, MnAs becomes paramagnetic at $T_C \sim 312$ K via a first order transition with a hysteresis of about ± 6 K. At T_C, the structure changes from the hexagonal NiAs-type to the orthorhombic MnP-type structure, which is a slightly distorted NiAs-type structure. Upon further heating, the NiAs-type structure is restored at 393 K. On substituting a small amount of the Mn atoms in MnAs by other transition metals (V,Cr,Fe,Co,Ni) or substituting As by P, the MnP-type structure can be stabilised down to ~ 4.2 K. The unit cell of the MnP-phase is slightly contracted and hence it would be expected that the MnP-phase can be stabilized by applying a pressure as well as by alloying. By means of neutron diffraction, we have investigated the effect of hydrostatic pressure on powdered MnAs and confirmed that at 4.2 K the MnP-type structure appeared at ~ 8 kbar and above. The magnetic ordering in this phase is no longer ferromagnetic but rather a modulated magnetic structure with a propagation vector of $0.125\vec{a}^*$ at 12.6 kbar and 4.2 K.

Authors: (35,46,6)

1.1.8. Spin waves in metallic glasses of $Fe_xSi_{90-x}B_{10}$ studied by neutron scattering

Amorphous alloys (metallic glasses) containing magnetic, metallic atoms have been studied extensively in recent years mainly because of their potential technological applications. In contrast to ordered crystalline magnetic materials the magnetic excitations in metallic glasses are not fully understood although it has been found* that well defined spinwaves do exist up to at least 0.25 $Å^{-1}$. We used low-angle neutron inelastic scattering to study the magnetic excitations of $Fe_xSi_{90-x}B_{10}$ metallic glasses at room temperature and somewhat above. Up to wave vector transfers of 0.12 $Å^{-1}$ well defined spin waves were observed. The magnon dispersion relations were found to display the same q dependence as those found for the acoustic spin waves in crystalline ferromagnets. The spin wave stiffness constant (D) increases according to a $T^{5/2}$ law with decreasing temperature, and extrapolates to D = (190±10) meV $Å^2$ and D = (220±10) MeV $Å^2$ at T = 0 K for $Fe_{81}Si_9B_{10}$ and $Fe_{75}Si_{15}B_{10}$, respectively. The renormalised spin wave stiffness constants at 0 K for $Fe_xSi_{90-x}B_{10}$ and Fe_xB_{100-x} deduced from neutron inelastic scattering are nearly twice as large as those deduced from the magnetisation data. The origin of this discrepancy is being investigated.

*Axe, J.D., Shirane, G., Mizognchi, T. and Yamauchi, K. (1977). Phys. Rev. B15, 2763.

Authors: (79,6,3,28,43)

1.1.9. Magnetic ordering of antiferromagnetic $Nd_{1-x}Pr_x$

The magnetic ordering of Nd metal has been investigated over many years and it is known that several modulated magnetic structures appear at low temperatures. Recent magnetic susceptibility measurement (H. Boghossian and B.R. Coles, private communication 1983) on single crystals of $Nd_{1-x}Pr_x$ indicate that the low temperature behavior of the alloys is similar to Nd. The addition of Pr to Nd reduces T_N steadily from 19.9 K to ~ 15 K at 35% Pr. The series of low temperature anomalies which in Nd is observed between 8.3 and 5.8 K may correspond to the susceptibility anomalies observed at 7.6 and 4.4 K in Nd 75% Pr 25%. We have initiated a neutron diffraction study of $Nd_{1-x}Pr_x$ to investigate how the magnetic ordering of Nd is modified by alloying. The experiment was done at the four-circle instrument D10 at ILL (Grenoble) using the special (spherical tail section) four-circle flow cryostate. This study confirmed the T_N values found by the susceptibility measurements, and showed magnetic Bragg peaks in the alloys (x = 25% Pr and 35% Pr) similar to those observed in Nd between 19.9 and 8.3 K. However, down to 2.9 K we did not observed any anomalies in the diffraction patterns from the alloys, which could be ascribed to changes of magnetic structure similar to those previously observed in Nd between 8.3 and 5.8 K.

Authors: (76,6,99)

1.1.10. Fermi surface of dhcp Pr

We have determined the Fermi surface of dhcp Pr from self consistent relativistic LMTO calculations including spin-orbit coupling. The Fermi surface is found to consist of two cylinders in the 5th and 6th bands running along ΓA, a multiply connected sheet in the 7th band, and a cylinder in the 8th band running along KH. The calculated extremal areas and cyclotron masses compare favorably with recent preliminary de Haas van Alphen (dHvA) experiments. The overall mass enhancement is found to be approximately 6.5. It is our intention to extend the study to dhcp La.

Authors: (32,97,78)

1.1.11. Superconductivity in lanthanides and actinides

The superconducting transition temperature T_c is determined primarily by the electron-phonon coupling parameter λ. McMillan showed that λ in turn may be written as a product of the Hopfield parameter η which characterize the electronic response to the displacement of an atom and the inverse of an average square phonon frequency $\langle\omega^2\rangle$. In the present work we have estimated η from first principles band calculation for La, Lu, and Th over a pressure range of approximately 50 GPa as well as for the light actinides Pa-Pu at normal conditions. Using empirical estimates of average phonon frequencies we hope to be able to understand the variation of T_c in these metals both as a function of atomic number and as a function of pressure.

Authors: (32,78)

1.1.12. Crystal structures from first principles calculations

The crystal structures of the elemental metals tend to occur in certain sequences both as a function of atomic number and as a function of pressure. In order to understand these trends we have extended previous calculations of the structural energies using the so-called force theorem to include the 3d, 4d, and 5d transition metals together with the lanthanides and the light actinides. Included in the study are the fcc, bcc, hcp, dhcp, Sm-type, bct and α-U crystal structures. The calculations show that for the less closely packed crystal structures, e.g. α-U and bct the treatment of the electrostatic contribution needs improvement. For the closely packed structures, however, the theory gives an accurate description of the crystal structures observed experimentally as function of atomic number and pressure.

Authors: (32,62)

1.1.13. Studies of the spin-Peierls transition of TTF-(Cu)BDSe

The quasi-one-dimensional organic salt TTF-(Cu)BDSe has been studied by X-ray diffraction technique. Magnetic susceptibility measurements suggest that this salt in analogy with its sulphur counterpart TTF-(Cu)BDT, undergoes a spin-Peierls transition. The purpose of the study was to verify the spin-Peierls ground state and to investigate the SP induced structural ordering as a function of an applied magnetic field.

The study was complicated by an additional structural transition, occurring at approximately 10°C, which caused the sample to rotate typically 8-10°. It was, though, possible to predict the orientation of the crystal below the transition temperature, and thereby get the right scattering plane into the rather narrow window of the 100 kGauss magnet, in which the crystal had to be studied. Going through the transition more than once, usually destroyed the sample.

Below 6 K additional reflections, proving the spin-Peierls ground state, appeared. The reflections showed that the SP ordering cause dimerization along the 1 D (stacking) axis, whereas the other two principal axes remained unchanged. Unfortunately, the reflections induced by the SP ordering were very weak, and apparently very sensitive tc irradiation damage. Therefore, we were not able to do any more quantitative measurements and not able to study the effect of applying magnetic field.

Authors: (80,31,5)

1.1.14. Transport properties of salts of TMTSF and TMTTF

The transport properties (conductivity σ and thermopower S) of the two groups of organic salts, $(TMTSF)_2X$ and $(TMTTF)_2X$ as well as the solid solution $(TMTSF_{1-x}TMTTF_x)_2X$, has been studied. Analysis of the data gives evidence of significant Coulomb repulsion (Hubbard U) only on TMTTF salts. The Hubbard U doubles the Fermi wave vector and brings thereby E_F to midband in coincidence with the gap due to dimerization. Thus, the $(TMTTF)_2X$ salts shows semiconducting properties. The $(TMTSF)_2X$ salts have, on the contrary, metallic behaviour at high temperature. The Hubbard U also explains the different effect anion-ordering have on the properties of respectively TMTTF and TMTSF salts.

$(TMTSF)_2BrO_4$ exhibits unique transport properties, which we have analyzed in terms of variable-range hopping among localized charge carriers. The localization is attributed to the anions which are ordered only over short ranges.

Authors: (31,61,36,40,44)

1.1.15. Defect structure of Y_2O_3-stabilised ZrO_2 and its dynamical behaviour at high temperatures

Yttria-stabilized zirconia has many uses as an oxygen-ion conductor. In order to investigate the static and dynamic behaviour of the defect structure, coherent diffuse neutron scattering from single crystal samples of 9.4, 12, 15, 18 mole % Y_2O_3 in ZrO_2 has been investigated. At 293K the diffuse scattering in the (110) plane shows a characteristic distribution of intensity with scattering vector which changes systematically as the dopant level is increased. The temperature variation of the scattering from the 9.4 mole % sample has been investigated up to 1733K and a complete distribution of intensity in the (110) plane has been measured. At the highest temperatures the scattering becomes quasielastic, although the integrated intensity retains the same distribution in reciprocal space. A detailed investigation of the weak scattering along (100) revealed an interesting dependence on scattering vector of both intensity and energy width. Attempts are currently being made to interpret the data in terms of clusters of displaced ions. The life time of the cluster decreasing with increasing temperature.

Authors: (3,60,82,54,73,4)

1.1.16. Conductivity, structural and thermodynamic studies of fluorite type of ionic conductors

The studies of pure and doped ionic conductors with the fluorite type of crystal lattice have been continued. The thermodynamic model for fluorites, which has been developed with the purpose of studying the thermal generation of defects from specific heat measurements, has been extended to include calculations of the ionic conductivity. With only two adjustable parameters in addition to those derived from specific heat studies it has been possible to give a satisfactory account for the ionic conductivity data of $Pb_{1-x}U_xF_{2+2x}$ with x = 0, 0.05 and 0.10.

Diffuse neutron scattering from heavily doped $Ba_{1-x}La_xF_{2+x}$ (x = 0.492) showed evidence for short range correlations between 222-type defect clusters. To investigate these correlations further, the room temperature intensity of the diffuse peaks centered at $(h\pm\frac{2}{3},k,\ell)$, $(h,k\pm\frac{2}{3},\ell)$ and $(h,k,\ell\pm\frac{2}{3})$ were examined up to $h^2+k^2+\ell^2 = 10$ ((h,k,ℓ) are reciprocal lattice vectors for the fluorite lattice). The 222-cluster is uniaxial in character, and the ionic disorder can be visualized as an assembly of aggregates, where an aggregate consists of aligned close packed 222-type clusters.

Authors: (4,3,5)

1.1.17. Structure, ionic conductivity and specific heat of new fast ionic conductors: $MTaCl_6$ (M = Na,K)

The ionic compounds $MTaCl_6$ (M = Na,K) formed by melting of stoichiometric amounts of MCl and $TaCl_5$ have proven to form a new interesting group of fast ionic conductors. The transition to the fast ionic phase, which in both cases is observed in the ionic conductivity as a discontinuous increase by two orders of magnitude occurs at rather low temperature (T = 168°C and 127°C, respectively). The ionic conductivity observed for $KTaCl_6$ at 300°C: $\sigma = 0.1\ \Omega^{-1}\ cm^{-1}$, is the highest value reported for potassium conduction. The discontinuous changes in the ionic conductivities are consistent with the structural studies by neutron powder diffraction which reveal three crystallographic phases of which the high temperature α-phases both have cubic symmetry. The phase transitions are also evident from specific heat studies but there are significant discrepancies in the transition temperatures compared to the ionic conductivity results.

It has been shown that $NaNbCl_6$ has similar physical properties and it is expected that mixtures of niobium and tantalum compounds may have lower transition temperatures to the fast ionic phase.

Authors: (4,3,84)

1.1.18. Structural studies of the intercalation system $Li_xV_6O_{13}$

$Li_xV_6O_{13}$($x \leq 8$) is a lithium intercalation material with potential applicability as cathode material in lithium batteries. The electromotive force relative to lithium metal reveals three flate plateaus which correspond to filling up a total of one (2.76 V), four (2.54 V) and eight (2.16 V) lithium ions per V_6O_{13}. This behaviour is usually interpreted to result from three regions composed of two-phase materials. However, it has been shown to be consistent with a simple model which assumes statistical distribution of non-interacting lithium ions on three types of energetically different sites in the lattice. Neutron diffraction studies have been initiated to study the structural properties of the intercalation process. Diffraction patterns have been recorded at room temperature for four different compositions (x = 0, 1, 2.1 and 7.5) and structural analyses by use of the EDINP-refinement program are in progress. The results from V_6O_{13} deviate from the structure deduced from X-ray single crystal data (space group C2/m), probably due to lack of stoichiometry in the vanadium-oxygen ratio.

Authors: (4,98)

1.1.19. Smectic layering in the nematic phase of free surface liquid crystals*

The spectrometer set-up can furnish an arbitrary wavevector transfer $\vec{Q}$ between the wavevectors of the incident beam, $\vec{k}_{in}$, and the scattered beam, $\vec{k}_{out}$, while maintaining a horizontal liquid surface, ref. 1. The very long lateral correlation of the surface layers in real space implies an extremely narrow cross section in reciprocal space which we may take as a delta-function in the transverse component of $\vec{Q}$. This selection rule then enables an elegant separation between surface scattering and bulk scatttering, the first being confined to the Q_z-axis and the latter yielding diffuse scattering around (001). The surface scattering intensity at wavevector transfer Q relative to that from Fresnel scattering from a medium with the same average density is given by the derivative, f'(z), of the normalized density profile f(z):

$$I(Q)/I_F(Q) = \left| \int_{-\infty}^{\infty} f'(z)\exp(-iQz)dz \right|^2$$

The data are modelled by the sum of two density distribution functions, one generating a surface field for layering with a penetration depth of a few layers at all temperatures, the other being the response to such a field with a temperature-dependent penetration depth which we have previously found to coincide with the bulk, longitudinal correlation range+.

+ Als-Nielsen, J., Christensen, F. and Pershan, P.S. (1982). Phys. Rev. Lett. 48, 1107.

Authors: (1,9,83,39,38,96)

1.1.20. Epitaxial growth of Xe on graphite studied by synchrotron X-ray diffraction*

Physisorbed layers on graphite substrates have been studied extensively by synchrotron X-ray diffraction. The main emphasis has been on the phase transitions in the first adsorbed layer because it approximates a two-dimensional system. We have now performed a series of diffraction measurements on the system Xe adsorbed on graphite in order to study the different kinds of transitions occurring when the thickness of the adsorbed layer is increased from a monolayer to bulk Xe. The same technique as described earlier using a multigrain substrate, the UCAR ZYX graphite, has been applied.

Three different regimes can be identified as function of film thickness: (1) a monolayer has an incommensurate triangular structure, (2) at about two layers the first of them is compressed and become commensurate with the graphite surface in a $\sqrt{3}\times\sqrt{3}$ structure, while the second layer has a more open structure. For more than 3 layers the interphase changes again and the Xe-film attain the bulk Xe-lattice structure for all layers. Several phase transitions are involved which will be studied in more details in experiments in preparation.

Authors: (9,10,8)

*The experiments were performed at the triple-axis spectrometer at Hasylab, DESY, Hamburg.

1.1.21. Synchrotron x-ray diffraction on Si(111) surfaces

With the triple-axes spectrometer in HASYLAB we have initiated x-ray diffraction measurements on single crystalline surfaces. The aim is to study the long range order of the surface layers or interphase layers and the phase transitions involved. Such studies require ultra high vacuum containment of the samples and techniques for sample preparation with sputtering, annealing etc.

In order to gain experience with the diffraction technique involving single crystal surfaces we have looked at the surface X-ray scattering from a Si(111) surface in atmospheric air.

A horizontal scattering spectrometer was used and the Si crystal surface aligned using the total reflected beam. Data were collected with the position sensitive detector (PSD), perpendicular to the surface and Bragg reflections by the direct beam and by the total reflected beam were observed.

In addition strong scattering from Bragg rods perpendicular to the surface were seen. The latter originates from surface layers a few atomic distances thick and with long range order parallel to the surface.

Authors: (9,10,8,1,33,37,75,47,63)

1.1.22. Protein-DNA complexes studied by small angle neutron scattering

SANS studies of the interaction of DNA-dependent RNA-polymerase with promotors have been initiated. The project aims at a detailed characterization of the polymerase enzyme, of the DNA segment and of the complex in various degrees of deuteration so as to give structural insight in the transcription process. The first promising experiments showed the need for DNA-segments shorter than 800 Å and a new procedure to obtain these has now been developed at the Max Planck Institute for Biochemistry at Martiensried, F.R.G. The project will continue in 1984.

Authors: (5,2,57,68)

1.1.23. RNA-protein and protein-protein interactions studied by small-angle neutron scattering

Small-angle neutron scattering (SANS) has been used to study conformational changes occurring as a result of complex formation between RNA and protein. As an example was chosen the ternary complex formed between the E. Coli elongation factor Tu (EF-Tu), GTP, and valyl-$tRNA^{Val}_{1A}$ at the D_2O concentrations where the protein and tRNA are matched by the solvents, respectively. The results showed insignifiant structural change upon complex formation. Protein-protein interactions have been studied on the α_2-macroglobulin system (α_2M). From the contrast dependence of the gyration radius, using both SAXS and SANS, it is indicated that within the α_2M-molecule the regions of higher electron density are located closer to the centre than the regions of lower electron density. As shown by SAXS, α_2M forms 1:2 complexes with both trypsin and chymotrypsin. It also forms the mixed 1:1:1 complex with both trypsin and chymotrypsin. Simultanously, α_2M undergoes a large conformational change as indicated by the disappearance of the side maximum from the scattering curve. Surprisingly, this pronounced conformational change can be simulated by methylamine: this suggests that the key reaction for the conformational change is the breaking of a γ-glutamylthiol ester bond in each subunit rather than a limited proteolysis.

Authors: (91,101,5,2)

1.1.24. Diffusion of polymers studied by SANS

The diffusion of polymer chains in a melt has generated a great deal of recent interest. According to the theory of de Gennes, the diffusion on a microscopic scale may be envisaged by the reptation of the chain along a tube formed by the entanglements of neighbouring molecules. More recent theoretical and experimental data indicates, however, that the entanglements are fairly flexible, and thus the concept of the fixed tube may be somewhat misleading.

Small angle neutron scattering experiments can be used for directly investigating the diffusion process. In the present study a sandwich-like polyethylene sample, composed of alternating films of respectively fully deuterated and fully protonated material, was used. Since the thickness of the individual layers was of the order of 50 μm, the sample did not give rise to small angle scattering. When, however, the temperature is raised above the melting point, T_m, deuterated molecules diffuse into the protonated layers (and vice versa), thereby causing small angle scattering. With typical diffusion times of the order of hours, it is possible to study the diffusion process in real time by SANS.

The experiment, which will be continued in 1984, will include different polymers and studies of the dependence of various molecular parameters.

Authors: (5,31,93)

1.1.25. Precipitation of γ'-particles in nickel-base alloys studied by SANS

Most nickel-base superalloys are strengthened by a combination of two mechanisms: 1. Precipitation hardening by ordered γ'-particles with the composition $Ni_3(Al_xTi_{1-x})$. 2. Solid solution hardening in the matrix. To achieve a basic understanding of the precipitation mechanisms in this type of alloys, samples were prepared from a model system Ni with 12 at% (Al,Ti). To get the Al-Ti in solid solution the samples were first heated for 1 hour at 1050°C, followed by heat treatment in the temperature range 550-650°C for 30 min - 28 h. to get precipitation of γ'-particles (sizes ranging from approximately 5-300 Å). The small angle neutron scattering spectra for samples annealed for a given time at a given temperature were measured with neutron wavelength λ = 5 Å, 18 Å and 31 Å. The analysis of the corresponding Guinier-plots, to get the distribution of particle sizes in the sample, are in progress.

Authors: (12,56,95,5)

1.1.26. Investigation of static correlations in aggregated SiO_2 by SANS

Computer simulations of the Diffusion Limited Aggregation process (DLA) have shown that the density function, $\rho(r)$, varies as r^D with $D \simeq 2.5 \neq 3$ (!) on a certain length scale. D is interpreted as an effective fractal dimension, the Hausdorff dimension. Aggregated SiO_2 (Cab-O-Sil) produced by the hydrolysis of $SiCl_4$ in a flame of H_2 and O_2 is believed to be a physical example of the DLA model. Systematic measurements of small angle neutron scattering from Cab-O-Sil samples with different densities have shown that the scattering data can be interpreted as being due to a fractal dimension D = 2.7 inside the clusters. Electron microscopy and contrast variation experiments on Cab-O-Sil dispersed in H_2O/D_2O are expected to show whether a particle size distribution interpretation of the data is possible. Furthermore a dispersion of the aggregates in water is expected to disentangle these causing the aggregate-aggregate correlation effect to be reduced.

Authors: (90,11,5)

1.1.27. Bubbles in 600 MeV proton irradiated Al by small angle neutron and x-ray scattering

The radiation damage in thin foils (0.1 mm) of high-purity Al after high dose (1.5 dpa) exposure to 600 MeV protons at SIN, Switzerland, has been studied using the Risø SANS facility and an x-ray Kratky camera at the University of Gothenburg, Sweden. The proton irradiation gives rise to the formation of bubbles in the material because helium atoms are generated during 600 MeV proton irradiation. The aim of the project is to provide a quantitative characterization of the size-distribution and the He-content in the bubbles and of the variation along the proton beam profile. The results for a 1.5 dpa specimen exposed at 369°C show a predominance of bubbles with radius of gyration R_g = 25 nm and a He atomic density corresponding to half of the aluminium atomic density. However, the deduced total concentration of He exceeds considerably the expected concentration; a careful analysis of possible systematic errors in the derived size distributions is in progress. The He-content in the bubbles is derived from a comparison of the neutron and x-ray absolute cross sections; the scaling procedure has been checked by comparison of the scattering from Al-samples containing small Al_2O_3-particles. This comparison gave a good agreement within 20%.

Authors: (89,5,91)

1.1.28. Neutron measurements of textures in Al containing large intermetallic particles

The presence of large intermetallic Fe-Al particles (with sizes ranging from one to several micrometers) in commercially pure aluminium (99.4%) affect the recrystallization behaviour as they act as potential nucleation sites. The presence of these particles might therefore effect the texture developing during recrystallization, and a study of this has been commenced by in-situ neutron diffraction pole figure measurements, and by transmission- and high voltage-electron microscopy observations. Sample parameters were the initial grain size and the degree of deformation (15, 30, 50, 90, 95 pct. reduction in thickness by cold rolling). It is observed that the recrystallized grains positioned close to large particles have preferred orientations close to the rolling texture components (~10° FWHM). The final recrystallized texture consists of these broadened rolling texture components, some random texture and (as for pure materials) a cube component which strength increases with increasing deformations. The work is going to be continued by selected area channelling measurements in a scanning electron microscope to study the development of the specific texture components.

Authors: (12,59,53)

1.1.29. Texture inhomogeneity in the cold-rolled and recrystallized state of fcc metals

The macroscopic inhomogeneity of texture introduced in the rolling process, is mainly caused by the shearing of metal in the rolling gap*. The intensity of the shear deformation depends upon the geometry of the rolling gap as well as upon the physical proporties of the material, and varies through the material (perpendicular to the rolling plane). The rolling texture of a surface layer therefore differs from the texture of the bulk. Two sets of Cu, Al and brass (~ 30 wt % Zn) samples were prepared to study this effect. Both sets were cold rolled to ~ 70% reduction in thickness, set 1 in few steps (Δh ~ 1.8 mm reduction in thickness per pass in the rolling mill) and set 2 in many steps (Δh ~ 0.2 mm). Pole figures of these samples were measured by neutron diffraction, and it is observed that the textures of the set 1 samples consist of the bulk texture components (seen in the set 2 samples) plus the expected shear texture components. By fast in-situ pole figure measurements the change in texture is followed during recrystallization, the analysis of this data are in progress.

*Truszkowski, W., Król, J. and Major, B. (1982). Metall. Trans. 13A, 665-669.

Authors: (12,74,69)

1.1.30. Texture development during grain growth in pure Cu

If annealing is continued at elevated temperatures after the completion of primary recrystallization, grain boundaries migrate further through the recrystallised structure, thereby increasing the average grain diameter. The changes in texture during this grain growth process have been studied in cold drawn copper rods using a neutron diffraction method for fast, in-situ pole figure measurements. The material used was pure Cu (99.999%), and grain growth was performed isothermally at several different temperatures in the range 450-800°C. It is observed that the <111> fibre component strengthen during the growth at the expense of the <100> component, and that the ratio <111>/<100> increases with increasing grain growth temperatures.

Authors: (12,53,51,85)

1.1.31. Crystallisation of metallic glasses studied by synchrotron x-ray diffraction

Metallic glasses containing Fe are soft magnetic materials with potential technological applications. When crystallizing they become brittle and lose their magnetic properties. We have perperformed test experiments of the crystallisation process in metallic glasses by means of x-ray synchrotron radiation and the energy dispersive diffraction technique, which enable the recording of a full diffraction pattern in a relatively short time. The amorphous to crystalline transition were investigated in $Fe_xSi_{90-x}B_{10}$, with $69 < x < 83$. We used the white x-ray spectrum of DORIS (Hasylab, F.R.G.) in the energy range up to 60 keV which for the scattering angle $2\theta = 21^o$ corresponds to a maximum scattering vector of 11 $Å^{-1}$. The crystallization was followed either by heating step wise from 20°C to 1000°C or by repeatedly recording the diffraction patterns obtained while annealing the sample at a fixed temperature close to the crystallization temperature or above.

When annealing $Fe_{83}Bi_7B_{10}$ at 350°C Bragg peaks appear which can be identified as α-Fe. A time series of isothermal diffraction patterns show that at 350°C the crystallization of α-Fe is nearly complete after ~ 700 minutes. The kinetics may be described by the phenomenological Avrami equation, yielding $n = 1.3$. Annealing at 438°C result in another set of Bragg peaks which tentatively were identified as Fe_2B.

Authors: (79,88,6,28,43)

1.1.32. Neutron diffraction experiments on ordered copper nuclei at nanokelvin temperatures - a feasibility study

The interest in investigating nuclear order in copper at nanokelvin temperatures by neutron-diffraction techniques has arisen from the successful nuclear susceptibility measurements performed in Otaniemi. These experiments have shown that the copper nuclear spins order antiferromagnetically in a first-order transition at $T_c = 60$ nK. From this feasibility study it was concluded that a neutron experiment on copper does not seem to face any probihitive technical difficulties. The same two-stage nuclear-demagnetization cooling technique as used in Otaniemi can be employed with some modifications in the sample region. Furthermore, the magnetic Bragg reflections are expected to produce strong enough intensities to be detected in the short time intervals of about 10 min. available for the measurements before the sample warms up through the transition.

Authors: (3,58,64,71,72,86,92)

1.1.33. New focussing monochromator and vertically scattering spectrometer for synchrotron x-ray diffraction

At the thriple axes spectrometer on beam line D4 in Hasylab, DESY, Hamburg all measurements until recently have been done with a spectrometer moving on air cushions and scattering in the horizontal plane. This geometry is very convenient when a cryostat, or similar equipment is used to hold the sample, but better intensity and resolution can be obtained by using a vertical scattering geometry. Therefore a vertical scattering double monochromator has been built and installed in beamline D4 and it is used in combination with a new spectrometer also scattering in the vertical plane.

The monochromator consists of two Si(111) crystals, the second being curved so that focussing in the horizontal plane is achieved.

The new spectrometer is a 4-circle instrument with ϕ, χ, θ and 2θ arms. The diameter of the χ-circle is 40 cm. The entire instrument can be craned in or out of the hutch through the roof. The beamline and the electrical cabling is made so that it is easy to change over from one spectrometer to the other. When the wiggler beam line is ready the new spectrometer will also be used at that beam.

Authors: (1,17,9,23,25,8)

1.1.34. The four-circle neutron diffractometer

The four-circle neutron diffractometer has been used to collect the necessary data to solve several crystallographic problems. In addition it has been widely used to orient crystalline samples.

A group from the Chemical Institute, University of Århus, Denmark has used the diffractometer extensively to solve more chemically oriented crystallographic problems. Two of these studies aim at investigations of the electron distribution by analysis of combined x-ray and neutron diffraction data. The mineral bromellite, BeO, adopts the wurtzite rather then the zincblence structure and the traditional ionic model is inadequate indescribing the physical properties of crystalline BeO. The neutron diffraction study is intended to give accurate positional and thermal parameters as a basis for the analysis of the electron distribution to be derived from the x-ray diffraction data.

The metallo organic cage compound Λ-Co (sepulchrate)$(NO_3)_3$ shows very strong temperature dependence of the circular dichroism, which may be attributed to movement of the hydrogen bonded NO_3-ions. The room temperature neutron diffraction study - which will be followed by low temperature studies, when the DISPLEX cooling system (grant 11-3355 from SNF) becomes operational in 1984 - will form the basis for an investigation of the sensitivity of the circular dichroism to the outer sphere configuration.

Authors: (66,81,6,55,65)

1.1.35. Liquid N_2 and He plant

The delivered quantities of liquid N_2 and He amounted to 150000 and 14000 litres, respectively. Out of these amounts 6000 litres of liquid He were delivered to laboratories in Copenhagen, Odense, and Aarhus.

Authors: (20,19,8)

1.2. Participants in the work in condensed matter physics

Scientific Staff

1. Als-Nielsen, J. (1.1.19,1.1.21,1.1.33)
2. Bauer, R. (1.1.22,1.1.23) (until February 1, 1983)
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4. Hessel Andersen, N. *(1.1.15,1.1.16,1.1.17,1.1.18)
5. Kjems, J.K. (1.1.3,1.1.4,1.1.5,1.1.13,1.1.16,1.1.22,1.1.23, 1.1.24,1.1.25,1.1.26,1.1.27)
6. Lebech, B. (1.1.6,1.1.7,1.1.8,1.1.9,1.1.31,1.1.34)
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8. Nielsen, M. (1.1.20,1.1.21,1.1.33,1.1.35)

Ph.D. Students

9. Bohr, J. (1.1.19,1.1.20,1.1.21,1.1.33)
10. Feidenhansl, R. (1.1.20,1.1.21)
11. Freltoft, T. (1.1.26)
12. Juul Jensen, D.* (1.1.25,1.1.28,1.1.29,1.1.30)

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13. Astradsson, L.
14. Frederiksen, L.
15. Jørgensen, B.
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19. Christensen, K. (1.1.35)
20. Jensen, J.Z. (1.1.35)
21. Jensen, L.G.
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23. Linderholm, J. (1.1.33)
24. Lund, M.
25. Munck, J. (1.1.33)
26. Søndergaard, O.
27. Thuesen, A.

Guest Scientists

28. Buras, B. (1.1.8,1.1.31)	University of Copenhagen, Denmark
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30. Mackintosh, A.R.	University of Copenhagen, Denmark
31. Mortensen, K.+(1.1.13,1.1.14, 1.1.24)	SNF grant
32. Skriver, H.L. +(1.1.10,1.1.11, 1.1.12)	Risø and Nordita, Copenhagen, Denmark
33. Toney, M. (1.1.21)	Nato grant

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+ Supported by the Danish Natural Science Research Council

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81.	Nielsen, M.H. (1.1.34)	University of Århus, Denmark
82.	Osborn, R. (1.1.15)	Clarendon Laboratory, Oxford, U.K.
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2.3. Publications and educational activities

2.3.1. Publications

ALS-NIELSEN, J. (1983). An example of progress and future perspectives in X-ray synchrotron diffraction studies. Risø-M-2375.

ALS-NIELSEN, J. and PERSHAN, P.S. (1983). Synchrotron X-ray diffraction study of liquid surfaces. Nucl. Instr. Method 208, 545-548.

ANDERSEN, N.H., CLAUSEN, K., and KJEMS, J.K. Heavily doped $M_{1-x}U_xF_{2+2x}$ fluorites studied by quasielastic neutron scattering (M = Ba) and specific heat measurements (M = Pb). Solid State Ionics 9+10, 543-548.

ANDERSEN, N.H., POULSEN, F.W., and EICHINGER, G. (1983). Conductivity, structure, and specific heat of $LiBiO_2$. Solid State Chemistry 1982, Proceedings of the Second European Conference, Studies in Inorganic Chemistry 3 H.J.M. Heijligers and J. Schoonman, edited by R. Matselaar, 287-290.

ARONSSON, R., KNAPE, H.E.G., LUNDEN, A., NILSSON, L., TORELL, L.M., ANDERSEN, N.H., and KJEMS, J.K. (1983). Solid sulphate electrolytes; the first examples of a strange ion transport mechanism. Radiation Effects 75, 79-84.

BLASCHKO, O., KLEMENCIC, R., FRATZL, P., WEINZIERL, P., ERNST, G., EDER, O.J., and KJEMS, J.K. (1983). Deuterium short-range order in $Pd_{0.975}Ag_{0.025}D_{0.685}$ by diffuse neutron scattering. Phys. Rev. B28, 3579-3581.

BOHR, J., KJÆR, K., NIELSEN, M., and ALS-NIELSEN, J. (1983). Use of a position sensitive detector for data acquisition of synchrotron X-ray diffraction from adsorbed gas monolayers on graphite. Nucl. Instr. Meth. 208, 555-558.

BOHR, J., NIELSEN, M., ALS-NIELSEN, J., KJÆR, K., and McTAGUE, J.P. (1983). Synchrotron x-ray study of physisorbed films of mixtures of Ar and Xe on graphite. Surface Science 125, 181-187.

BURAS, B. (1983). High pressure research with synchrotron radiation. Nuclear Instruments and Methods 208, 563-568.

BURAS, B. (1983). The European Synchrotron Radiation Project, ESRP report PG-2/83, 14 pages, CERN, Geneva.

BURAS, B., FARGE, Y., and THOMPSON, D.J. (1983). Synchrotron Radiation Facilities in Europe, Symposium on International Facilities for Physics Research, EPITOME, Risø, Denmark, 63-73.

BURAS, B., FOURME, R., and KOCH, M.H.J. X-ray diffraction, principles and applications, (in) Handbook on Synchrotron Radiation, Vol. IC, 1015-1090, North-Holland.

CLAUSEN, K., HAYES, W., HUTCHINGS, M.T., KJEMS, J.K., MACDONALD, J.E., and SCHNABEL, P. (1983). Neutron scattering investigation of disorder in UO_2 and ThO_2 at high temperatures. High Temperature-High Pressure 15, Part 4, p. 383-90.

CLAUSEN, K., HUIKU, M.T., JYRKKIØ, T.A., LOPONEN, M.T., LOUNASMA, O.V., ROACH, P.R., and SKÖLD, K. (1983). Neutron diffraction experiments on cupper nuclei at nano-kelvin temperatures. A feasibility study. TKK-F-A529, 1-38.

DOVE, M.T., HEILMANN, I.U., KJEMS, J.K., KURITTU, J., and PAWLEY, G.S. (1983). A neutron scattering study of phonons in perdeuterated s-triazine. Phys. Stat. Sol. (b) 120, 173-181.

FEILE, R., KNORR, K., KJEMS, J.K., FRICK, B., and LOEWENHAUPT, M. (1983). Anomalous linewidths of the crystal electric field excitations in $La_{0.997}Tm_{0.003}Al_2$ below the superconducting transition. J. Phys. C. 16, 1465-1469.

HÄLG, B., FURRER, A., KJEMS, J.K., and VOGT, O. (1983). Magnetic excitations in CeAs, an effective S = 1/2 fcc antiferromagnet. Phys. Rev. Lett. 50, 1085-1088.

JOHANNSEN, I., BECHGAARD, K., MORTENSEN, K., and JACOBSEN, C. (1983). Dibenzotetraselenafulvalene (DBTSF). Synthesis and conducting salts. J. Chem. Soc. Chem. Commun. 1983, 295-296.

JONG, M.H. de, and KJEMS, J.K. (1983). Inelastic neutron scattering from dilute magnesium-rare-earth single crystals. J. Phys. F. 13, 1187-1195.

JUUL JENSEN, D. and KJEMS, J.K. (1983). Apparatus for dynamical texture measurements by neutron diffraction using a position sensitive-detector. Textures and Microstructures 5, 239-251.

KJEMS, J.K., ANDERSEN, N.H., SCHOONMAN, J., and CLAUSEN, K. (1983). Structure and dynamics of disordered solids: A neutron scattering study of $Ba_{1-x}La_xF_{2+x}$, Physica 120B+C, p. 357-361.

KJEMS, J.K., KAKURAI, K., and STEINER, M. (1983). Neutron scattering study of spin fluctuations in $CsNiF_3$ without applied field. J. Magn. Magn. Mater. 31-34, 1133-1134.

KJÆR, K., NIELSEN, M., BOHR, J., LAUTER, H.F., and McTAGUE, J.P. (1983). Synchrotron x-ray study of submonolayers of CF_4 on graphite. Surface Science 125, 171-180.

LEBECH, B., ANDERSEN, N.H., STEENSTRUP, S., and SCHRØDER PEDERSEN, A. (1983). Neutron diffraction studies of ytterbium-dihydride. The crystal structure at 300 K. Acta Crystallogr. C39, 1475-1480.

LEUENBERGER, B., GÜDEL, H.U., FEILE, R., and KJEMS, J.K. (1983). Collective excitations in the singlet ground-state dimer system $Cs_3Cr_2Br_9$. Phys. Rev. B28, 5368-5370.

LINDGÅRD, P.-A. (1983). Theory of singlet-doublet systems showing a soft mode and a central peak. J. Magn. Magn. Mater. 31-34, 1099-1100.

LINDGÅRD, P.-A. (1983). Theory of spin waves in a sinusoidial phase. J. Magn. Magn. Mater. 31-34, 603-604.

LINDGÅRD, P.-A. (1983). Correlation theory for one dynamical variable: Application to EuO and EuS. Phys. Rev. B27, 2980-2991.

LINDGÅRD, P.-A. (1983). Correlation theory of planar magnets for $T > T_c$. Phys. Rev. Lett. 50, 690-693.

LINDGÅRD, P.-A. (1983). Theory of excitations in the 1-d singlet ground state magnet $CsFeCl_3$. Physica 120B+C, 190-192.

HUTCHINGS, M.T., CLAUSEN, K., DICKENS, M.H., HAYES, W., KJEMS, J.K. and SMITH, C. (1983). Investigation of thermally induced anion disorder in fluorites using neutron scattering techniques. AERE-R 11127-MPD-NBS-244, 95 pp.

LOIDL, A., HAUSSÜHL, S., and KJEMS, J.K. (1983). Elastic properties of CsCN. Z. Phys. B50, 187-192.

LOIDL, A., KNORR, K., FEILE, R., and KJEMS, J.K. (1983). Inelastic neutron scattering study of the structural glass transition. Phys. Rev. Lett. 51, 1054-1057.

MAAROUFI, A., COULON, C., FLANDROIS, S., DELHAES, P., MORTENSEN, K., and BECHGAARD, K. (1983). Physical properties of $(TMTSF)_2TaF_6$: influence of the anion size. Solid State Commun. 48, 555-559.

MACKINTOSH, A.R. (1983). Neutron scattering and magnetism. Inst. Phys. Conf. Ser. 64 (The Neutron and its Applications, edited by P. Schofield), 199-214.

McEWEN, K.A., VETTIER, C., and LEBECH, B. (1983). Uniaxial stress dependence of the magnetic structure of neodymium. J. Magn. Magn. Mater. 31-34 (pt. 1), 171-172.

MOON, R.M., LEBECH, B., and THOMPSON, J.R. (1983). Sublattice susceptibilities of neodymium metal. Phys. Rev. B27, 354-358.

MORTENSEN, K. (1983). X-ray diffuse scattering study of the organic conductor DBTTF-$TCNQCl_2$. Nucl. Instr. Meth. 208, 559-562.

MORTENSEN, K., CONWELL, E.M., and FABRE, J.M. (1983). Thermopower studies of a series of salts of tetramethyltetrathiafulvalene, $[(OTMTTF)_2X$, X = Br, ClO_4, NO_3, SCN, BF_4, AsF_6 and $PF_6]$. Phys. Rev. B28, 5856-5862.

NIELSEN, M., BOHR, J., KJÆR, K., ALS-NIELSEN, J., and McTAGUE, J.P. (1983). Synchrotron x-ray diffraction applied to the study of physisorbed monolayers. Nucl. Instr. Method 208, 549-553.

NIELSEN, M. and BURAS, B. (1983). ESRF - beamline for 3-axes spectrometer optimized for the study for long-range ordered surface studies, ESRP report IRI-6/83, 10 pages, CERN, Geneva.

NIELSEN, M., KJÆR, K., BOHR, J., and McTAGUE, J.P. (1983). X-ray and neutron diffraction measurements on physisorbed films on graphite. J. of Electron Spectrosc. and Relat. Phenom. 80, 111-118.

NIELSEN, M., BOHR, J., KJÆR, K., and McTAGUE, J.P. (1983). Diffraction measurements on physisorbed films. Proceedings of the International Conference on Neutron and its Application (Cambridge 1982), edited by P. Schofield, Inst. of Phys. Conf. Ser. No. 64, 1983.

NIKSCH, M., ASSMUSS, W., LÜTHI, B., ÖTT, H.R., and KJEMS, J.K. (1982). Low temperature structural and magnetic properties of $PrPb_3$. Helvetica Physica Acta 55, 688-698.

POULSEN, F.W., ANDERSEN, N.H., KINDL, B., and SCHOONMAN, J. Properties of LiI-Alumina composite electrolytes. Solid State Ionics 9+10, 119-122.

SKRIVER, H.L. (1983). Electronic structure and cohesion in the rare earth metals. Systematics and the Properties of The Lanthanides edited by . S.P. Sinha (D. Reidel Publ. Co. 1983), 213-249.

STASSIS, C., ZARETSKY, J., MISEMER, D.K., SKRIVER, H.L., and HARMON, B. (1983). Lattice Dynamics of fcc Ca. Phys. Rev. B27, 3303-3307.

STEINER, M., KAKURAI, K., and KJEMS, J.K. (1983). Experimental study of the spindynamics in the 1-D ferromagnet with planar anisotropy $CsNiF_3$ in an external magnetic field. Z. Physik B53, 117-142.

WULFF, M., JENSEN, J., MACKINTOSH, A.R., BJERRUM MØLLER, H., McMASTERS, O.D., and GSCHNEIDNER, Jr., K.A. (1983). Excitations of neodymium ions in praseodymium. J. Magn. Magn. Mat. 31-34, 601-602.

1.3.2. Conference contributions

ALS-NIELSEN, J. Surface structure of liquid crystals studied by synchrotron X-ray diffraction. Eight European Crystallographic Meeting, Liége, Belgium (August).

ANDERSEN, N.H., CLAUSEN, K., and KJEMS, J.K. Neutron scattering and specific heat of the ionic conducting fluorites XF_2(X=Ba,Pb) doped with UF_4. Danish Physical Society, Spring Meeting, Nyborg Strand, Denmark (May).

ANDERSEN, N.H., CLAUSEN, K., and KJEMS, J.K. Heavily doped $M_{1-x}U_xF_{2+2x}$ fluorites studied by quasielastic neutron scattering (M = Ba) and specific heat measurements (M = Pb). 4th International Conference on Solid State Ionics, Grenoble, France (July).

BURAS, B. High pressure research with synchrotron radiation. Synchrotron Radiation Seminar, Copenhagen, (January).

BURAS, B. The European Synchrotron Radiation Project. Symposium on Perspectives on Synchrotron Radiation Research at Small Storage Rings, Lund, Sweden (April).

BURAS, B. The European Synchrotron Radiation Project. The New Ring Workshop, Standford Synchrotron Radiation Laboratory, Stanford University, U.S. (July).

BURAS, B., FARGE, Y., and THOMPSON, D.J. Synchrotron Radiation Sources in Europe. Symposium on International Facilities for Physics Research, Copenhagen, Risø, Denmark (March).

CLAUSEN, K., KJEMS, J.K., HAYES, W., SCHNABEL, P. and SMITH, C. Coherent quasielastic diffuse neutron scattering from fluorites in the fast-ion phase. Danish Physical Society, Spring Meeting, Nyborg Strand, Denmark (May).

FEILE, R., KJEMS, J.K., LEUENBERGER, B., GÜDEL, H.V. Collective excitations in a system of dimers: A neutron scattering study of $Cs_3Cr_2Br_9$. Danish Physical Society, Spring Meeting, Nyborg Strand, Denmark (May).

GIEBULTOWICZ, T., MINOR, W., KEPA, H., BURAS, B., LEBECH, B., and GALAZKA, K.K. Neutron scattering studies of $Cd_{1-x}Mn_xTe$. 29th Annual Conference on Magnetism and Magnetic Materials, Pittsburgh, Pennsylvania, U.S.A. (November).

KJEMS, J.K. Phase transitions; experimental methods. Danish Physical Society, Winter School, H.C. Ørsted Institute, University of Copenhagen, Denmark (January).

KJEMS, J.K., ANDERSEN, N.H., CLAUSEN, K., and SCHOONMAN, J. Defect clusters and ionic mobility in $Ba_{1-x}La_xF_{2+x}$. 4th International Conference on Solid State Ionics, Grenoble, France (July).

KJEMS, J.K., HÄLG, B., FURRER, A., and VOGT, O. Magnetic excitations in CeAs, an effective S = 1/2 fcc antiferromagnet. Danish Physical Society, Spring Meeting, Nyborg Strand, Denmark (May).

LEBECH, B., BERNHARD, J., and BECKMAN, O. The low temperature magnetic structure of hexagonal FeGe. Danish Physical Society, Spring Meeting, Nyborg Strand, Denmark (May).

LINDGÅRD, P.-A. Soft mode and central peak as a consequence of competing interactions. Nato Advanced Study Institute on "Multi Critical Phenomena", Geilo, Norway (April).

LINDGÅRD, P.-A. Soft mode and central peak as a consequence of competing interactions. Danish Physical Society, Spring Meeting, Nyborg Strand, Denmark (May).

LINDGÅRD, P.-A. Correlation theory for one and two dynamical variables: Heisenberg and planar magnets for $T > T_c$. Meeting on Theoretical Magnetism, Institute of Physics, Oxford, U.K. (June).

LINDGÅRD, P.-A. Phase transitions and critical phenomenon. Fysik Dagar, Swedish Physical Society, Uppsala, Sweden (November).

MINOR, W., SCHÖNFELD, B., LEBECH, B., BURAS, B., and DMOWSKI, W. Crystallization of metallic glasses studied by means of synchrotron radiation. 19. Danske Krystallografmøde, Sandbjerg Slot, Als, Denmark (June).

MINOR, W., KEPA, H., GIEBULTOWICZ, T., BURAS, B., LEBECH, B., and CLAUSEN, K. Magnetic behaviour of Fe-Si-B metallic glasses studied by neutron scattering. Europhysics Conference on Soft Magnetic Materials 6 (SMM 6), Budapest, Hungary (September).

MORTENSEN, K. Thermopower studies of organic salts of TMTSF and TMTTF. Danish Physical Society, Spring Meeting, Nyborg Strand, Denmark (May).

MORTENSEN, K. Properties of organic salts of TMTSF and TMTTF. NATO Advanced Study Institute on Physics and Chemistry of Electrons and Ions in Condensed Matter, Cambridge, UK (September).

NIELSEN, M. and BURAS, B. (1983). ESRF-Beamline with three-axes spectrometer optimized for the study of long-range ordered surface structures. European Synchrotron Radiation Project, Workshop Schloss Nordkirchen, F.R.G. (October).

OSBORN, R., ANDERSEN, N.H., CLAUSEN, K., HAYES, W., HUTCHINGS, M.T., and MACDONALD, J.E. Defect structure of Y_2O_3-stabilised ZrO_2 and its dynamical behaviour at high temperatures. Institute of Physics, Solid State Physics Conference, Oxford, UK (December).

POULSEN, F.W., ANDERSEN, N.H., KINDL, B., and SCHOONMAN, J. Properties of LiI-Alumina composite electrolytes. 4th International Conference on Solid State Ionics, Grenoble, France (July).

SKRIVER, H.L. Crystal structures from first principles calculations. 13th Annual International Symposium on Electronic Structure of Metals and Alloys. Jonsbach, G.D.R. (May).

SKRIVER, H.L. Elementary theory of actinides under pressure. Actinides under Pressure. Karlsruhe, F.R.G. (April).

SkKRIVER, H.L. Status of bandstructure calculations for the actinides. Actinides Electronic Structure Workshop. Los Alamos, New Mexico, USA (August).

1.3.3. Lectures

ALS-NIELSEN, J., European synchrotron radiation facility - at Risø? Kemisk Forening, University of Copenhagen, Denmark (April).

ALS-NIELSEN, J., Synchrotron X-ray diffraction study of dislocation-free liquid crystals. Talk at the Inauguration of the X-ray laboratory, Hebrew University, Jerusalem, Israel (May).

ALS-NIELSEN, J., Synkrotron røntgenstråling brugt på studium af dislokationsfrie flydende krystaller. Technical University of Trondheim, Norway (June).

ANDERSEN, N.H., Physical properties of some fast ionic conductors. University of Copenhagen, Denmark (November).

BURAS, B., The use of synchrotron radiation in condensed matter physics, Clarendon Laboratory, Oxford University, U.K. (April).

BURAS, B., The European Synchrotron Radiation Project, Saclay, France (October).

JUUL JENSEN, D., A fast in-situ texture-measuring technique, and its use for investigating recrystallization kinetics. Zentralinstitut für Kernforschung, Rossendorf bei Dresden, G.D.R. (May).

KJEMS, J.K., The Risø SANS-facility. EMBL-outstation, DESY, Hamburg, F.R.G. (February).

KJEMS, J.K., Collective excitations in unusual magnets.
1) University of Utrecht, The Netherlands (June).
2) University of Copenhagen, Denmark (October).
3) University of Århus, Denmark (November).

LEBECH, B., The magnetic structure of Nd-metal, a "single-$\vec{q}$" or "multi-$\vec{q}$" modulated structure?. University of Uppsala, Uppsala, Sweden (May).

LINDGÅRD, P.-A., Correlation theory for an antiferromagnet in a field.
1) Rutherford Laboratory, Chilton, U.K. (June).
2) Cavendish Laboratory, Cambridge, U.K. (July).

LINDGÅRD, P.-A., Magnetic excitations. Hahn Meitner Institute, Berlin (August).

LINDGÅRD, P.-A., Phase transition and critical phenomena. University of Århus, Denmark (December).

MORTENSEN, K., Organiske metaller og superledere. Polymerteknisk Selskab: Elektrisk ledende polymere. H.C. Ørsted Institute, University of Copenhagen, Denmark (May).

SKRIVER, H.L., Crystal structures from first principles calculations.
1) University of Düsseldorf, Düsseldorf, F.R.G. (April).
2) KFA, Jülich, F.R.G. (April).
3) Lawrence Livermore Laboratory, Livermore, California, USA (September).
4) University of Copenhagen, Denmark (November).

2.1. Introduction to the work in plasma physics

During 1983 the scientific programme included the following main objects:

(i) A study of pellet-plasma interaction with the aim of assessing possibilities of refuelling a fusion reactor by shooting deuterium-tritium pellets into the plasma. The study is divided into the following subsections.
(a) A detailed study of the interaction between charged particles of various energies and solidified gases.
(b) A direct investigation of the interaction between pellets and a plasma performed in the tokamak DANTE and in TFR at Fontenay-aux-Roses (Paris) in cooperation with the TFR group.
(c) Pellet handling, acceleration and injection.
(d) Theoretical pellet ablation studies.

(ii) Construction of a Thomson scattering equipment for JET, carried out under contract with JET.

(iii) A study of electron cyclotron resonance heating of high density tokamak plasmas including theoretical investigations of ray tracing and energy deposition in the tokamak geometry and preparations for an electron cyclotron resonant heating experiment at DANTE.

(iv) A study of the fundamental physics of plasmas including theoretical as well as experimental investigations of wave propagation properties, convective cells, instabilities, solitons, turbulence, plasma diffusion etc.

2.1.1. Erosion of solidified gases by keV electrons

Two experimental methods for measuring the erosion of condensed gases have been studied. One method, the frequency-change method, utilizes a quartz-crystal microbalance operating at liquid-helium temperature. A second method, the emissivity-change method, is based on the strongly varying electron emission as a function of the condensed-gas film thickness. Satisfactory results have been obtained for both methods for solid Ne and D_2 at electron energies up to 3 keV, and the mutual agreement is good. In particular, erosion measurements on solid neon have been advantageous, since solid Ne has a relatively large erosion yield (28 Ne-atoms/electron for 2 keV primary electrons) without being so volatile as solid D_2. The agreement for solid HD and H_2 is less satisfactory. Measurements on these gases will be carried out in the coming year. A remarkable transition from dominant electron sputtering to beam-induced evaporation has been observed for 2 keV electrons on solid Ne. The similar transition for the hydrogen isotopes will be investigated as well.

Authors: (16,12,13)

2.1.2. Penetration of keV ions and electrons in solid O_2 and CO

The range of keV electrons in solid CO and O_2 has been studied. These atoms are important constituents of tissue-equivalent gases, and the measurements have been carried out for the electron energies around the most probable energy for electron ejection from β-decay of tritium. The electron range in solid O_2 was slightly smaller than the previously measured range in solid N_2, whereas the range in solid CO was larger than the range in N_2.

The ranges of 1.3-3.5 keV/atom hydrogen and deuterium molecular ions have been measured by a thin-film reflection method. The main aim was to look for phase-effects, i.e. gas-solid differences in the stopping processes. While measured ranges in solid O_2 were in agreement with known gas data, the ranges in solid CO were up to 50% larger than those calculated from gas-stopping data. The latter result agrees with that previously found for solid N_2.

Authors: (12,13,67,53,38)

2.1.3. DANTE (Danish Tokamak Experiment)

The efforts on DANTE have been concentrated on development of new diagnostics and on improvements of already existing diagnostics.

For a detailed study of the pellet trace curvature, a position sensitive detector is under installation. Measured data from the detector may be transferred directly to the computer, and an investigation of the fast electron influence on the pellet may be performed.

The coming ECRH (Electron Cyclotron Resonance Heating) experiment on DANTE made an improvement of the Thomson scattering equipment relevant. A new set-up has been designed. This set-up features simultanous measurements at five different positions and will enable calculation of the plasma temperature profile.

The plasma density is measured by a CO_2-laser interferometer. To obtain a more stable output power the laser has been modified. Firstly the CO_2 gas is now flowed continously through the laser tube, whereby the accumulation of impurities in the gas is prevented. Secondly a new flexible mount of the Brewster windows has been introduced. This will minimize the influence on the windows arising from thermal fluctuations at the laser tube end-points.

Authors: (2,15)

2.1.4. Diagnostics for deuterium pellets

A design proposal concerning equipment to diagnose deuterium pellets injected into tokamaks was made under contract with IPP-Garching. The design offers measurements of both mass and velocity of the pellet. The measurement of pellet mass exploits the characteristics of a microwave cavity tuned close to resonance and working on the flank of the resonance peak. When a pellet of frozen deuterium enters the cavity, the resonance conditions will be changed. This may be converted to a measurable signal proportional to the mass of the pellet. The velocity of the pellet is measured in an optical arrangement involving two sets of diodes. Each set consists of a light emitting diode placed opposite to a photosensitive diode. During the passage of the pellet a voltage pulse results as the light intensity at the photosensitive diode decreases. The velocity may now be calculated from the time difference between pulses from the two photosensitive diodes. The joint equipment is designed to withstand high radiation fields and may be remote controlled. The design proposes a complete data aquisition system. The design has been accepted for use on JET, and is considered for use on ASDEX at Garching.

Authors: (2,15)

2.1.5. Development of deuterium pellet injector systems

A pneumatic pellet gun of improved and versatile design has been built. The cryogenic part allows fast filling of solid deuterium and quick change of gun barrel. It is actually possible to change pellet size and velocity from one day to another. The gun was used for acceleration of pellets of various lengths and diameters of 1.4 and 1.8 mm in gun barrels of various lengths. Velocities up to 1400 m/s were obtained. The spread in velocity may be as low as ± 1% and the spread in size as low as ± 2%. Acceleration of hydrogen and neon pellets has also been made successfully.

Experiments with pellet transport through guide tubes of nylon were made. 1.4-mm pellets with velocities up to 1260 m/s were transported successfully, i.e., with small percentage of broken pellets, through a 4 m long guide tube with a minimum radius of curvature of 2 m.

Small pellets of acryl (10 mg) have been accelerated to velocities above 1100 m/s by means of an electrical discharge made in a confined space behind the pellet. Earlier attempts to use this method for deuterium pellets failed, probably because the pellets were not cold enough. It will now be attempted to use this method again in a cryostat of improved design.

Authors: (13,1,25,24,29,30,32,14)

2.1.6. Pellet injection in the tokamak TFR at Fontenay-aux-Roses, Paris

The pellet injector system that was mounted at the mock-up of TFR in October 1982 was moved to the tokamak in February. It was used here first time in March. The guide tube, through which the pellets are transported to the tokamak, was realigned in April.

The injector has been used 10 days for various experiments in 1983 and it has worked well without major problems.

Authors: (13,1,29,32,14,60)

2.1.7. Pellet ablation simulation code

To use the program PELLETINT/F as a simulation code of the experiments, the original FORTRAN-700 version written at Risø was further modified to be acceptable by the Solar used on TFR at the Fontenay-aux-Roses. In view of the experiments performed at TFR, further additional features were made, these include (a) the actual temperature and density profiles measured in each experiment, (b) the including of H_β-emission profile besides the H_α-emission profile, (c) the possible absorption of L_α-line, (d) the actual pellet trajectory.

Authors: (3,62,52)

2.1.8. The effect of atomic processes on the neutral shielding model of a refuelling pellet

Atomic processes of dissociation and ionization of the ablatant from a pellet in a dense and hot plasma, corresponding to current large tokamak discharges, were studied. It was found that due to the atomic processes, the singular point of the momentum equation is no longer at the sonic point. By taking this finding into account, a proper initiation of the numerical integration procedure is formulated.

Authors: (3,18)

2.1.9. On the correlation between the H_α-line emission rate and the ablation rate of a hydrogen pellet in tokamak discharges

Following referees' suggestions, the paper is revised, and will be resubmitted to Nuclear Fusion for publication.
Authors (3,18)

2.1.10. Pellet-plasma interaction

In an existing model describing adiabatical cooling of the background plasma by a refuelling pellet an extension including the effects of finite diffusion of the ablatant along and across magnetic field-lines was formulated. Changes in the computational code are in preparation.

Authors: (3,18,38)

2.1.11. Single point Thomson scattering for JET (Joint European Torus)

The hardware for the input subsystem was delivered in March and assembly and test could take place. At an acceptance test witnessed by JET in April the successful operation of the subsystem was demonstrated. The test included the alignment subsystem on the ruby laser bench, the input labyrinth and the top and bottom benches. Also the principle of operation of the alignment units on the west wall was demonstrated.

In July a similar test of the collecting subsystem was performed. This test incorporated the vertical, small and horizontal mirrors as well as the spectrometer.

Parallel to manufacture, assembly and test control software for the remote control of the diagnostic was developed at Risø. This included programs for alignment of the input and collecting subsystem.

In the late summer the diagnostic was shipped to JET. Since then assembly and installation has been in progress. Software developed at Risø has been transferred to the JET computer system.

Authors: (9,4)

2.1.12. Electron cyclotron resonance heating of the DANTE plasma

During 1983 the construction of this experiment was initiated and the theoretical studies continued. A 20 kW klystron amplifier for a frequency of 17.5 GHz has been ordered and will be delivered at the end of April 1984. The 100 kW power supply for this klystron is under construction. The main idea of the experiment, which is to heat a high density plasma ($\omega_{peo} > \omega_{ceo}$) by utilizing a certain mode conversion process, was described last year*.

Other experiments on electron cyclotron heating of tokamak plasma have started recently on various small and medium size tokamaks, and experiments with power up to some megawatts are planned in several countries. However, only in the experiment planned for DANTE the mode conversion method will be investigated. To study microwave antenna radiation patterns, lenses etc., a microwave test room has been equipped. A good knowledge of the plasma temperature during the heating is very important. Preliminary studies of the possibility of using electron cyclotron emission for continuous measuring the electron temperature have been started.

* Risø Report R-491, p. 35

Authors: (17,7,8,69,14)

2.1.13. Current drive by electron Bernstein waves

A toroidal current is necessary for stability of a tokamak plasma and it seems to be a promising method to drive a current by injecting electromagnetic waves into the plasma. Furthermore, currents driven in this manner give a prospect of operating a tokamak in the steady state. A computer code developed for the electron cyclotron resonance heating (ECRH) experiment at the DANTE tokamak used for wave tracing has been improved to calculate the current driven by the waves. In order to do this, the code has been improved to calculate the deposited wave power. The code has been used to determine the radial current profile as well as the radial power deposition profile in the DANTE plasma. This has been done by modelling an antenna by a finite number of plane waves with different propagation vectors. So far we have used analytical results for the far field of a horn antenna.

Authors: (17,7,8)

2.1.14. Computer simulation of obliquely propagating electron Bernstein waves*

Electron Bernstein waves are electrostatic waves in a magnetized plasma with frequencies near the harmonics of the electron frequency. These waves are undamped if they propagate perpendicular to the magnetic field, but strongly damped when propagating at oblique angles. Electron Bernstein waves are used in plasma heating by microwaves when the plasma is cold, e.g. for tokamak start-up, or in connection with the mode conversion scheme for electron cyclotron resonance heating of high density plasmas. In order to directly study the interaction of Bernstein waves with plasma electrons a computer model was constructed which describes the evolution of plane, electrostatic waves launched by a localized exciter and propagating at an arbitrary angle to a magnetic field. The plasma ions are considered immobile and the motion of the electrons is described by one spatial coordinate and three velocity coordinates. Investigations are being performed on the effect of the non-linear wave-particle interaction on the wave length, the damping length, and the electron velocity distribution function.

*Work performed at University of California, Berkeley, U.S.A.

Authors: (7,47)

2.1.15. Electron-Bernstein waves in inhomogeneous magnetic fields

The propagation of small amplitude electron Bernstein waves in different inhomogeneous magnetic field geometries was investigated experimentally. Wave propagation towards both cut-offs and resonances were considered. The experimental results were supported by a numerical ray-tracing analysis. Spatial enhancements of the wave amplitude were interpreted as a result of caustic formation.

Authors: (10,39,45,61)

2.1.16. Convective cells

Convective cells were excited externally in a fully ionized, magnetized plasma in the Q-machine and the space-time evolution was investigated by two dimensional potential measurements (Sugai et al. 1983). The cells were identified by three basic properties: i) large ratios for the normalized potential/relative density perturbations, ii) they propagate with the bulk plasma drift (i.e. in the plasma rest frame the cells are purely damped), and iii) small damping rates. In the present set-up it was found that shear deformation, end losses and presumably also turbulent fluctuations rather than classical ion viscosity determined the damping rate. An externally excited positive cell in turn generated a cell with negative polarity. These two cells were found to propagate together without any significant interaction. Preliminary investigations of the interaction of two cells of the same (positive) polarity, however, indicates the possibility for coalescence. A detailed investigation of the general dispersion relation for low frequency modes (including the convective cell mode) in a magnetized collisional plasma was initiated. The equations for the temperature dynamics and finite wavelengths along the magnetic field gives rise to several new branches as compared with the standard treatment.
Sugai, H., Pécseli, H.L., Rasmussen, J.J., and Thomsen, K. (1983). Phys. Fluids 26, 1388.

Authors: (10,68,11,54,18)

2.1.17. The current driven electrostatic ion cyclotron instability*

Experimental investigations of the electrostatic ion cyclotron instability (EICI) are mainly performed in single-ended Q-machine plasmas, where the current is drawn to a small, circular disk placed in the center of the plasma column (e.g. Schrittwieser, 1983). To investigate the importance of this cylindrical geometry we performed experiments in the Innsbruck Q-machine in which the current was drawn to a strip collector crossing the entire plasma column. The EICI was easily excited also in this set-up when the width of the strip was few times the ion Larmor radius. However, for broader strips the EICI was dominated by low frequency instabilities and both drift waves and the potential relaxation instability were identified. The EICI was found to be confined within the current channel determined by the projection of the strip. Thus the cylindrical symmetry seems not to be necessary for the excitation of the EICI. Furthermore the existence of an azimuthal ion-ring beam surrounding the current channel seems not to be essential for the EICI as recently suggested (Schrittwieser, 1983) since such a ring beam cannot exist in the present set-up.
Schrittwieser, R. (1983). Phys. Fluids 26, 2250.
*Work performed at University of Innsbruck, Austria

Authors: (11,55,57)

2.1.18. Determination of electron hole velocity limits in the modified Maxwellian model

Electron holes are non-linear, electrostatic pulses of positive potential that can propagate along the field lines in a strongly magnetized plasma without change of shape. Theoretical calculations* based on a simple waterbag model have shown the only slow holes with velocities less than approximately the electron thermal velocity are allowed. This result was in good agreement* with results from experiments and numerical simulations. However, by applying a more detailed modified Maxwellian model of electron holes Schamel** found that the hole velocity either should be lower than certain limit, that was a little too low to account for all the simulation results, or higher than another limit, rising the possibility of highly supersonic holes. A new analysis of the modified Maxwellian model showed that the high velocities holes actually are not allowed by the theory and that finite amplitude effects on the maximum velocity limit brings the theory in perfect agreement with the simulation results.

*) Lynov, J.P. (1980). Risø-R-432, 107 pp.
**) Schamel, H. (1979). Phys. Scr. 20, 336-342

Author: (7)

2.1.19. Nonlinear evolution of the bump-on-tail instability

The nonlinear evolution of a single unstable mode in a system subjected to the bump-on-tail instability was investigated by means of a numerical simulation. The evolution was found to be in qualitative agreement with the theoretical results of Janssen and Rasmussen 1981 for a finite temperature beam. Thus the wave amplitude grew linearly and saturated while the distribution function was flattened around the phase velocity. However, the saturated level found in the simulations was always much lower than the theoretical predicted one. Several possibilities for explaining this discrepancy are under investigation. When the beam was cold a somewhat different behaviour was observed. The wave amplitude grew explosively, i.e. at a rate stronger than exponential, before saturation at a relative high level. This behaviour is in qualitative agreement with theoretical calculations for a cold beam.

Janssen, P.A.E.M., Rasmussen, J. Juul (1981). Phys. Fluids 24, 268.

Authors: (33,11)

2.1.20. A thermal modulational instability

The modulational instability of a high frequency (hf) plasma wave was considered in a magnetized weakly ionized plasma. In addition to the nonlinearity originating from the ponderomotive force we took into account the thermal nonlinearity due to the Ohmic heating of the electrons. These two effects act in an analogous way at least in nearly stationary situations and both tend to push plasma away from regions of excess hf-field intensity. For the thermal nonlinearity this displacement occurs indirectly: an excess heating occurs in regions of excess wave field causing a local temperature increase. The pressure increase associated with this temperature perturbation then forces the plasma away. Since the electron thermal conductivity is much larger along the magnetic field than across it the effects of the thermal nonlinearity are only important for almost perpendicular modulations. The effects of the ponderomotive force are equally important in all directions, at least for a weakly magnetized plasma. We have derived an equation for the hf wave field including both the effects of a pump field and dissipation. This equation is coupled with equations for the low frequency density response due to both ponderomotive and thermal nonlinearities. The dispersion relation for modulations of the hf wave was analysed and in general it is found that the instability arising from the thermal effects (mainly for almost perpendicular modulation) have the lowest threshhold but also a relatively low growth rate.

Authors: (10,11,36,18)

2.1.21. Thermally stimulated Brillouin scattering in plasmas

A theory for stimulated Brillouin scattering is formulated, where the dominant nonlinearity is the ohmic heating of the plasma. The analysis is carried out with particular reference to experimental investigations of CO_2 laser heating of a linear discharge plasma. In the conditions characterizing this experiment local heat conduction is of little importance and the dynamic evolution of the electron temperature is dominated by heating and energy exchange with the ion component. These features are incorporated in the analysis. The resulting equations give a growth rate and characteristic scale size for filaments which agrees well with the experimental results.

Authors: (10,43,34,58)

2.1.22. Nonlinear electrostatic wave equations for magnetized plasmas

The lowest order kinetic effects are included in the equations for nonlinear electrostatic electron waves in a magnetized plasma. The modifications of our previous analysis based on a fluid model are discussed. The new equation allows for the inclusion of weakly anisotropic electron energy distribution functions. Particular directions of wave propagation with respect to the magnetic field are investigated by the wave-packet formalism. The resulting equations contain the already known complex modified Korteweg-de Vries equation as a time stationary special case. Particular attention was given to directions of propagation along and across the magnetic field. These directions are particularly interesting by giving the possibility of "pancake" and "cigar" shaped solitary solutions.

Authors: (10,43,34,58)

2.1.23. Electromagnetic wave propagation in random media

The propagation of a narrow frequency-band beam of electromagnetic waves in a medium with randomly varying index of refraction is considered. A novel formulation of the governing equations is proposed. An equation for the average Green's function can then be derived by standard methods. A Fokker-Planck type equation is contained as a limiting case. The results are readily generalized to include the features of a random coupling model and it is demonstrated that the present problem is particularly suited for an analysis of this type. A description of beam wander and beam spread is derived from the governing equation.

Author: (10)

2.1.24. Self-similar collapse

The nature of collapsing solutions (i.e. solutions that approach a singularity in finite time) to the cubic Schrödinger equation (CSE):

$$iu_t + \nabla^2 u + |u|^2 u = 0 \qquad (1)$$

have been investigated by considering different similarity transformations. The CSE models the slow evolution of the complex envelope u of a wave train and applies to many branches of physics. For one dimensional cases CSE have soliton solutions, but for higher dimensions no stable stationary solutions exist and it is well known that collapse of the wave envelope may occur. We have considered a general similarity transformation of Eq. 1 by which the explicit time dependence is removed and Eq. 1 is transformed to two ordinary differential equations (for the modulus and phase of u). We have attempted to classify the different solutions of the transformed equations with the particular aim of finding a proper solution for describing the collapsing singularity. The self-similar solutions are compared with numerical solutions of Eq. 1 in radial symmetry.

Authors: (35,10,18)

2.1.25. Relative diffusion in plasmas

The growth of an initially small cloud of particles in a turbulent medium is described by a generalization of the Brownian motion, including a first stage of very slow initial relative diffusion, followed by a stage of rapid explosion of the cloud up to the final stage in which particles become uncorrelated, and Brownian diffusion is reached asymptotically. The stage of exponential growth, observed in fluid turbulence, corresponds to the clump effect in plasma turbulence. It is entirely due to the effect of trajectory correlations. Improvements are proposed for the theoretical methods describing relative diffusion of charged particles in a magnetoplasma, with reference to analogous methods used for diffusion studies of pollutants in the environment. Numerical results are presented for the effective radius of the cloud as function of time in the case of a model spectrum of drift-wave turbulence. When compared with classical Brownian diffusion of uncorrelated particles, the effective "diffusion coefficient" for correlated particles is found to be reduced by orders of magnitude for rather long times, as compared to the case of independently diffusing particles. The theory is generalized to account for the turbulent damping of convective cells.

Authors: (10,65,64,49,40,63)

2.1.26. Discovery of W and Z

The UA2 experiment at CERN has obtained a fairly large sample of proton antiproton collisions at 540 GeV cm-energy. In this sample the decays of the intermediate vector bosons Z and W have been observed. The UA1 detector has made similar discoveries. A review of the experimental work may be found e.g. in Europhysics News 14, 10 October 83, p. 1.
Collaborators on this project are: 1) K. Borer, B. Hahn, H. Hänni, P. Mani, J. Schacher, F. Stocker, 2) P. Bagnaia, F. Bonaudi, M. Borghini, A.G. Clark, P. Darriulat, L. Di Lella, P.-A. Dorsaz, D. Froidevaux, O. Gildemeister, J.R. Hansen, P. Hansen, T. Himel, V. Hungerbühler, P. Jenni. M. Livan, L. Mapelli, C. Onions, G. Parrour, F. Pastore, H. Plothow-Besch, A. Rothenberg, J.L. Siegrist, H.M. Steiner, G. Stimpfl, A. Weidberg, 3) J. Dines-Hansen, O. Kofoed-Hansen, B. Madsen, R. Møllerud, B. Nilsson, 4) J.-C. Chollet, L. Fayard, J.-M. Gaillard, B. Merkel, J.-P. Repellin, G. Sauvage, 5) C. Conta, M. Fraternali, G. Fumagalli, V.G. Goggi, A. Rimoldi, V. Vercesi, 6) R. Battiston, G.C. Mantovani, 7) M. Banner, E. Lancon, S. Loucatos, B. Mansoulié, M. Polverel, A. Roussarie, J. Teiger, H. Zaccone.
1) Bern University, Switzerland, 2) CERN, Switzerland, 3) Niels Bohr Institute, Copenhagen, Denmark, 4) Orsay, France, 5) Pavia Italy, 6) Perugia, Italy, and 7) Saclay, France.

Author: (6)

2.2. Participants in the work in plasma physics

Scientific Staff

1. Andersen, S.A. (2.1.5, 2.1.6)
2. Andersen, V. (2.1.3, 2.1.4)
3. Chang, C.T.* (2.1.7, 2.1.8, 2.1.9, 2.1.10)
4. Gadeberg, M.** (2.1.11)
5. Jensen, V.O.
6. Kofoed-Hansen, O. (part-time) 2.1.26
7. Lynov, J.P. (2.1.12, 2.1.13, 2.1.14, 2.1.18)
8. Michelsen, P. (2.1.12, 2.1.13)
9. Nielsen, P. (until July 31) (2.1.11)
10. Pécseli, H.L. (2.1.15, 2.1.16, 2.1.20, 2.1.21, 2.1.22, 2.1.23, 2.1.25, 3.1.6, 3.1.7)
11. Rasmussen, J.J. (2.1.16, 2.1.17, 2.1.19, 2.1.20, 2.1.24)
12. Schou, J. (2.1.1, 2.1.2)
13. Sørensen, H. (2.1.1, 2.1.2, 2.1.5, 2.1.6)
14. Weisberg, K.V. (part-time) (2.1.5, 2.1.6, 2.1.12)

Ph.D. Students

15. Bejder, H. (2.1.3, 2.1.4)
16. Ellegård, O. (from August 1) (2.1.1)
17. Hansen, P.R. (2.1.12, 2.1.13)
18. Thomsen, K. (2.1.8, 2.1.9, 2.1.10, 2.1.16, 2.1.20, 2.1.24)

Secretaries

19. Astradsson, L.
20. Frederiksen, L.
21. Jørgersen, B.
22. Kjøller, K.

Technical Staff

23. Andersen, P.
24. Borman, K. (2.1.5)
25. Bækmark, L. (from October) (2.1.5)
26. Hansen, B.H.
27. Jessen, M.***
28. Nielsen, M.O.
29. Nordskov, A. (2.1.5, 2.1.6)
30. Olsen, J. (until September 30) (2.1.5)
31. Reher, B.
32. Sass, B. (2.1.5, 2.1.6)

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* Seconded to Fontenay-aux-Roses, Paris, France
** Seconded to JET, Culham, England (from July 31)
*** Seconded to JET, Culham, England (from July 31)

Guest scientists

33. Janssen, P.A.E.M. (2.1.19)	Royal Netherlands Meteorological Institute, De Bilt, The Netherlands
34. Mjølhus, E. (2.1.21)	University of Tromsø, Norway
35. Rypdal, K. (2.1.24)	University of Tromsø, Norway
36. Tagare, S.G. (2.1.20)	University of Hyderabad, India
37. Tchen, C.M.	The City University of New York, U.S.A.

Short-time visitors and collaborators outside Risø

38. Andersen, H.H. (2.1.2)	University of Copenhagen, Denmark
39. Armstrong, R.J. (2.1.15)	University of Tromsø, Norway
40. Balescu, R. (2.1.25)	Université Libre de Bruxelles, Belgigue
41. Brundtland, T.	University of Tromsø, Norway
42. Drawin, H.W. (2.1.10)	Fontenay-aux-Roses, Paris, France
43. Dysthe, K.B. (2.1.21,2.1.22)	University of Tromsø, Norway
44. Esser, R.	University of Tromsø, Norway
45. Fredriksen, Å. (2.1.15)	University of Tromsø, Norway
46. Kritz, A.H.	City University of New York, U.S.A.
47. Lawson, W. (2.1.14)	University of California, Berkeley, U.S.A.
48. Milora, S.L.	Oak Ridge National Laboratory, U.S.A.
49. Misguich, J. (2.1.25)	Fontenay-aux-Roses, Paris, France
50. Nakamura, Y.	Inst. Space and Astronautical Science, Tokyo, Japan
51. Raadu, M.	Royal Institute of Technology, Stockholm, Sweden
52. Reverdin, C. (2.1.7)	Fontenay-aux-Roses, Paris, France
53. Rune, J. (2.1.2)	University of Copenhagen, Denmark
54. Scott, A.C.	Technical University of Denmark
55. Schrittwieser, R. (2.1.17)	University of Innsbruck, Austria
56. Singh, N.	Utah State University, Logan, U.S.A.
57. Skøelv, Å. (2.1.17)	University of Tromsø, Norway
58. Stenflo, L. (2.1.21,2.1.22)	University of Umeå, Sweden
59. Sugai, H. (2.1.16)	University of Nagoya, Japan
60. TFR-group (2.1.6)	Fontenay-aux-Roses, Paris, France
61. Trulsen, J. (2.1.15)	University of Tromsø, Norway
62. Wyller, J.	University of Tromsø, Norway
63. Xiaoming, Q. (2.1.25)	Southwestern Inst. of Physics, Sichuan, Peoples Republic of China

Collaborators inside Risø

64. Larsen, S.E. (2.1.25)	Physics Department, Meteorology Section
65. Mikkelsen, T. (2.1.25)	Physics Department, Meteorology Section
66. Rahbek, S. (2.1.7)	Computer Department, Risø

Students working for their Master's theses

67. Nielsen, M. (2.1.2)	University of Copenhagen, Denmark
68. Poulsen, S. (2.1.16)	Technical University of Denmark
69. Stobbe, N. (2.1.12)	University of Copenhagen, Denmark

2.3. Publications and educational activities

2.3.1. Publications

ANDERSEN, V., ANDERSEN, P., and CHRISTENSEN, P. (1983). Design of equipment for measuring pellet masses and velocities. Work done under contract to IPP-Garching, Germany for use at ASDEX (Garching) and JET (Culham) 42 pp.

ARMSTRONG, R.J., FREDRIKSEN, Å., PÉCSELI, H.L., and TRULSEN, J. (1983). Electron Bernstein waves in inhomogenous magnetic fields, Bull. Am. Phys. Soc. 28, 1069.

BANNER et al. (1983). A search for relativistic particles with fractional electric charge at the CERN pp collider. Phys. Lett. 121B, 187-192.

BANNER et al. (1983). Inclusive charged particle production at the CERN pp collider. Phys. Lett. 122B, 322-328.

BANNER et al. (1983). Observation of single isolated electrons of high transverse momentum in events with missing transverse energy at the CERN pp collider. Phys. Lett. 122B, 476-485.

BANNER et al. (1983). Preliminary searches for hadron jets and for large transverse momentum electrons at the SPS pp collider. Third Topical Workshop on Proton-Antiproton Collider Physics. Rome 12-14 January 1983, CERN 83-04, 10 May 1983, 190-216.

BAGNAIA and KOFOED-HANSEN, O. (1983). Measurement of production and properties of jets at the CERN pp collider. Z. Phys. C 20, 117-134.

BAGNAIA and KOFOED-HANSEN, O. (1983). Evidence for $Z^0 \rightarrow e^+e^-$ at the CERN pp collider. Phys. Lett. 128B, 130-140.

BØRGESEN, P., SØRENSEN, H. and CHEN Hao-Ming. (1983). Ranges, reflection and secondary electron emission for keV hydrogen ions incident on solid N_2, Nucl. Instr. Meth. 212, 517-528.

CHANG, C.T. (1983). Vaporization mode and state of the ablatant of a deuterium pellet in tokamak discharges. Phys. Fluids 26, 805-807.

CHANG, C.T. (1983). Ablation of a deuterium pellet in a fusion plasma viewed as a stopping power problem. Journal de Physique, Colloque C8, supplément au no. 11, 17-23.

CHANG, C.T. (1983). Some considerations of pellet injections in JET and INTOR. In: Proceedings of the 11th European Conference on Controlled Fusion and Plasma Physics, Aachen, F.R.G., September 5-9, ECA 7D, part I, pp. 131-133.

DINES HANSEN et al. (1983). Dobbelt-jets. Fysisk Tidsskrift 81, 45-47.

DINES HANSEN et al. (1983). W-partikler. Fysisk Tidsskrift 81, 47-48.

DYSTHE, K.B., MJØLHUS, E., PÉCSELI, H.L., and RYPDAL, K. (1983). A thermal oscillating two-stream instability. Phys. Fluids 26, 146-157.

DYSTHE, K.B., PÉCSELI, H.L., and TRULSEN, J. (1983). Stochastic generation of continous wave spectra. Phys. Rev. Lett. 50, 353-356.

DYSTHE, K.B., PÉCSELI, H.L., and TRULSEN, J. (1983). Stochastic generation of continous wave spectra. In: Proceedings of the XVI International Conference on Phenomena in Ionized Gases, Düsseldorf, August 29 - September 2, 5, 722-723.

GADEBERG, M. (1983). Thomsonspredning på høj og lavtemperatur plasma (Thomson scattering on high and low temperature plasmas). Risø-M-2378, 96 pp.

GADEBERG, M. and NIELSEN, P. (1983). High temperature Thomson scattering. Bull. Am. Phys. Soc. 28, 1154.

HANSEN, F.R., LYNOV, J.P. and MICHELSEN, P. (1983). ECRH of a high density plasma. In: Proceedings of the 11th European Conference on Controlled Fusion and Plasma Physics, Aachen, F.R.G., September 5-9, ECA, 7D, part I, pp. 293-296.

HOFER, W.O., GIBER, J., and SCHOU, J. (1983). Festkörperanalysen mittels Nachionisation zerstäubter Neutralteilchen. Fresenius Z. Anal. Chem. 314, 220.

IIZUKA, S., MICHELSEN, P., RASMUSSEN, J. Juul, SCHRITTWIESER, R., HATAKEYAMA, R., SAEKI, K., and SATO, N. (1983). Authors Respond to Comment by S. Kuhn. (Phys. Rev. Lett. 50, 217). Phys. Rev. Lett. 50, 218.

JANSSEN, P.A.E.M. and RASMUSSEN, J. Juul. (1983). Nonlinear evolution of the transverse instability of plane-envelope solitons. Phys. Fluids 26, 1279-1287.

JENSEN, V.O. (1983). The role of the JET project in global fusion research. Physica Scripta T5, 136-139.

JENSEN, V.O. (1983). Risø med i forsøg som kan sikre energi i milliarder af år (Risø involved in experiments which may provide energy for billions of years). Dansk Energitidsskrift, November, pp. 16-18.

JENSEN, V.O. (1983). Fusionsenergiens perspektiver (The perspectives of fusion energy). In: Report about the energy supply situation in the period up to 2030, prepared by the Energy System Group at Risø for the Ministry of Energy.

LYNOV, J.P. (1983). Modification of Korteweg-de-Vries solitons in plasmas by resonant particles. Phys. Fluids 26, 3262-3272.

LYNOV, J.P., MICHELSEN, P., HANSEN, F.R. (1983). ECRH of a high density plasma in the Dante tokamak. Bull. Am. Phys. Soc. 28, 1179.

LYNOV, J.P. and MICHELSEN, P. (1983). GANDALF - A generally applicable numerical data acquisition laboratory facility. Risø-M-2393, 77 pp.

PÉCSELI, H.L. (1983). Lecture Notes on Plasma Physics, Risø-M-2404, 150 pp.

PÉCSELI, H.L., MIKKELSEN, T.,and LARSEN, S.E. (1983). Drift wave turbulence in low-β plasmas. Plasma Physics 25, 1173-1197.

PÉCSELI, H.L., RASMUSSEN, J. Juul, and THOMSEN, K. (1983). Upper hybrid wave collapse in weakly magnetized plasmas. Phys. Lett. 99A, 175-179.

RASMUSSEN, J. Juul and THOMSEN, K. (1983). Damping and Frequency shift of large-amplitude electron plasma waves. Physica Scripta, 28, 501-509.

RYPDAL, K., RASMUSSEN, J. Juul, and THOMSEN, K. (1983). Comment on "Collapse of longitudinal waves in a pl sma". Phys. Rev. Lett. 51, 613.

SATO, N., HATAKEYAMA, R., IIZUKA, S., MIENO, T., SAEKI, K., RASMUSSEN, J. Juul, MICHELSEN, P., and SCHRITTWIESER, R. (1983). Stationary double layers in a collisonless magnetoplasma. J. Phys. Soc. Jap. 52, 875-884.

SUGAI, H., PÉCSELI, H.L., RASMUSSEN, J. Juul, and THOMSEN, K. (1983). Evolution of externally excited convective cells in plasmas. Phys. Fluids 26, 1388-1390.

SUGAI, H., PÉCSELI, H.L., RASMUSSEN, J. Juul, and THOMSEN, K. (1983). Convective cells. In: Proceedings of the XVI International Conf. on Phenomena in Ionized Gases, Düsseldorf, August 29 - September 2, 5, 720-721.

SØRENSEN, H., ANDERSEN, P., ANDERSEN, S.A., ANDERSEN, V., JENSEN, P.B., SKOVGÅRD JENSEN, H.E., NORDSKOV NIELSEN, A., SASS, B., and WEISBERG, K.-V. (1983). On the injection of deuterium pellets. In: Proceedings of the twelfth symposium on fusion technology, KFA Jülich, September 1982. Fusion Technology 1982, Pergamon Press, 1519-1523 p.

SØRENSEN, H., SCHOU, J., CHEN Hao-Ming, and BØRGESEN, P. (1983). Secondary electron emission from solid HD and a solid H_2-D_2 mixture. Surface Science 125, 355-365.

TRULSEN, J., DYSTHE, K.B., and PÉCSELI, H.L. (1983). Stochastic generation of wave spectra. Bull. of Am. Phys. Soc. 28, 1114.

2.3.2. Conference contributions

ANDERSEN, V. and BEJDER, H. Investigations on Pellets for Refuelling. Tenth Annual Conference on Plasma Physics, Bangor, England, 1983.

ARMSTRONG, R.J., FREDRIKSEN, Å., PÉSELI, H.L., and TRULSEN, J. Electron Bernstein Waves in Inhomogenous Magnetic Fields. 25th Annual Meeting, Division of Plasma Physics, American Physical Society, Los Angeles, U.S.A., November 7-11.

CHANG, C.T. Some considerations of pellet injections in JET and INTOR. 11th European Conference on Controlled Fusion and Plasma Physics, Aachen, F.R.G. September 5-9.

DYSTHE, K.B., PÉCSELI, H.L., TRULSEN, J. Stochastic Generation of Continuous Wave Spectra. XVI International Conference on Phenomena in Ionized Gases, Düsseldorf, F.R.G., August 29 - September 2, 1983.

GADEBERG, M. and NIELSEN, P. (1983). High temperature Thomson scattering. 25th Annual Meeting, Division of Plasma Physics, American Physical Society, Los Angeles, U.S.A., November 7-11.

HANSEN, F.R. Microwave heating of plasma at the electron cyclotron frequency. Spring meeting, Danish Physical Society, Nyborg, Denmark, May 10-11.

HANSEN, F.R., LYNOV, J.P., and MICHELSEN, P. ECRH of a high density plasma. 11th European Conference on Controlled Fusion and Plasma Physics, Aachen, F.R.G., September 5-9.

KOFOED-HANSEN, O. The discovery of the intermediate bosons Z^0 and $W^{\pm}$. Danish Physical Society, Annual Meeting, Niels Bohr Institute, Copenhagen, Denmark, November.

LYNOV, J.P., MICHELSEN, P., HANSEN, F.R. ECRH of a high density plasma in the Dante tokamak. 25th Annual Meeting of the Division of Plasma Physics, American Physical Society, Los Angeles, U.S.A., November 7-11.

PÉCSELI, H.L., RASMUSSEN, J. Juul, THOMSEN, K. and SUGAI, H. Externally excited convective cells. 18th Nordic Symposium on Plasma and Gas Discharge Physics, Geilo, Norway, February 13-16.

RASMUSSEN, J. Juul and JANSSEN, P.A.E.M. On the stability of solitons. 18th Nordic Symposium on Plasma and Gas Discharge Physics. Geilo, Norway, February 13-16.

RASMUSSEN, J. Juul, PÉSELI, H.L., SUGAI, H., and THOMSEN, K. Convective cells in plasmas. Danish Physical Society, Spring Meeting, Nyborg, Denmark, May 10-11.

SCHOU, J. Erosion of condensed gases by keV electrons. Spring Meeting at the Danish Physical Society, Nyborg. (May).

SCHOU, J., SØRENSEN, H., ANDERSEN, H.H., NIELSEN, M., RUNE, J. Range measurements of keV ions in solid oxygen and carbon monoxide. 10th International Conference on Atomic Collisions in Solids. Bad Iburg, F.R.G., July 18-22.

SUGAI, H., PÉCSELI, H.L., JUUL RASMUSSEN, J., THOMSEN, K. Convective Cells. XVI International Conference on Phenomena in Ionized Gases, Düsseldorf, August 29 - September 2, 1983.

SØRENSEN, H., ANDERSEN, P., ANDERSEN, S.A., ANDERSEN, V., NORDSKOV NIELSEN, A., SASS, B., and WEISBERG, K.-V. On the injection of deuterium pellets. Ninth International Vacuum Congress and Fifth International Conference on Solid Surfaces. Madrid, Spain, September 26-30.

SØRENSEN, H., SCHOU, J. and BØRGENSEN, P. Erosion of condensed gases by keV electrons. Ninth International Vacuum Congress and Fifth International Conference on Solid Surfaces. Madrid, Spain, September 26-30.

TFR group and Risø pellet injection group. Pellet injection in TFR plasmas. 11th Europeen Conference on Controlled Fusion and Plasma Physics, Aachen, F.R.G. September 5-9.

THOMSEN, K., PÉCSELI, H.L., and RASMUSSEN, J. Juul, Upper hybrid wave collapse in weakly magnetized plasmas. 18th Nordic Symposium on Plasma and Gas Discharge Physics, Geilo, Norway, February 13-16.

TRULSEN, J., DYSTHE, K.B., PÉCSELI, H.L. Stochastic generation of wave spectra. Annual Meeting Division of Plasma Physics, American Physical Society, Los Angeles, U.S.A. November 7-11.

2.3.3. Lectures

BEJDER, H. Om muligheden for bestemmelse af neutraltætheden omkring en pille indskudt i DANTE's plasma og om måling af absorptionstværsnit for lave røntgenenergier. (On the possibility for the determination of the density of neutrals around a refuelling pellet in the DANTE plasma, and on measuring the absorption crossection of low X-ray energies). Technical University of Denmark, Lyngby, Denmark (August).

CHANG, C.T. SRFC and STGI at Fontenay-aux-Roses, Paris, France (June). Three talks on: Implications and limitations of the neutral shielding model of the pellet ablation.

HANSEN, F.R. Exercises in Plasma Physics I (A lecture series on plasma physics and fusion research). Technical University of Denmark, Lyngby, Denmark (Autumn).

JENSEN, V.O. Plasma Physics I and II. (Two lecture series on plasma physics and fusion research). Technical University of Denmark, Lyngby, Denmark.

KOFOED-HANSEN, O. Lectures about Z^0 and W. Risø (September) and Dansk Fysisk Selskabs Årsmøde (November).

LYNOV, J.P. ECRH and current drive in a high density plasma.
1) University of California, Berkeley, U.S.A. (October).
2) Lawrence Livermore National Laboratory, Livermore, U.S.A. (October).

LYNOV, J.P. Comparison of waterbag and modified Maxwellian models of Gould-Trivelpiece electron holes with particle simulation results. University of California, Berkeley, U.S.A. (October).

MICHELSEN, P. Plasmafysik og fusionsenergi (Plasma physics and fusion energy). Ungdommens Naturvidenskabelige Forening, H.C. Ørsted Institutet (February).

MICHELSEN, P. Fusionsenergi (Fusion energy). Grenå Gymnasium (March).

MICHELSEN, P. Risø og fremtidens energikilder (Risø and the energy sources of the future). Kastrup-Tårnby Soroptimist-klub (May).

MICHELSEN, P. Electron cyclotron heating of a Tokamak plasma. Institute of Nuclear Science, Beograd (November).

MICHELSEN, P. RF-heating of Tokamak plasma, Technical University of Beograd (October).

MICHELSEN, P. Heating of a Tokamak plasma. Institute of Physics, Beograd (November).

PÉCSELI, H.L. Lectures at Nordic Research Course on Radiation and Scattering Processes in Space Plasmas, Sigtuna, Sweden, June 6-15.
1) Laboratory investigations of phenomena in plasmas (2 lectures)
2) Korteweg-de Vries solitons (2 lectures)
3) Random wave reflection (1 lecture).

PÉCSELI, H.L. Chalmers Institute of Technology, Gotherburg, Sweden (November).
1) External excitation of convective cells in plasmas.
2) Random wave reflection.
3) Ion phase space vortexes and their relation to ion-ion beam instabilities.

PÉCSELI, H.L. Random wave reflection. University of Umeå, Umeå, Sweden. (October).

PÉCSELI, H.L. Royal Institute of Technology, Stockholm, Sverige.
1) Ion phase space vortexes, experiment, and theory (October).
2) Convective cells in plasmas (June).

PÉCSELI, H.L. Scattering of μ-waves in laboratory plasmas. Danish Space Research Institute, Lyngby, Denmark (March).

PÉCSELI, H.L. Excitation of convective cells in plasmas. The University of Tromsø, Norway (April).

RASMUSSEN, J. Juul. Q-machine experiments at Risø. Danish Space Research Institute Lyngby, Denfmark (March).

RASMUSSEN, J. Juul. Double layer experiments in Q-machines. Royal Institute of Technology, Stockholm, Sweden (September).

RASMUSSEN, J. Juul. Convective cells in plasmas. University of Innsbruck, Innsbruck, Austria (November).

Rasmussen, J. Juul. Externally excited convective cells. Ruhr Universität, Bochum, F.R.G. (December).

THOMSEN, K. Transiente effekter i forbindelse med udbredelsen af ulineære højfrekvente bølger i et homogent plasma. (Transient effects of nonlinear wave propagation in homogeneous plasmas). Technical University of Denmark. Lyngby, Denmark. (May).

3. METEOROLOGY

3.1. Introduction to work in meteorology

Synoptic meteorology and weather forecasting is outside our scope of work which rather is concentrated on the study of turbulent processes in the atmospheric boundary layer. This includes a range of subjects such as: surface energy balance studies, of importance for example in such diverse areas as road administration (icing conditions) and bio-meteorology (evaporation and shelter effects); studies of the general structure of atmospheric coherence, and boundary layer response to change in surface elevation, both of interest in civil and wind power engineering; and specific studies of turbulent dispersion and deposition of airborne material (evaluation of air pollution potentials). Due to the latter being partly a climatological problem, climatology is also considered a subject which must be covered. Further, data aquisition and measurement techniques are necessary dicipli-nes. In the later years research and development in the utilization of wind energy has become a particular subject (evaluation of wind resources, turbulent effects on generator performance). The activities of The Test Plant for Small Wind Mills, although part of the Meteorology Section, are reported in a separate chapter (4) to give further opportunity to out-line the working programme.

3.1.1. Wind speed and direction changes due to terrain effects revealed by climatological data from two sites in Jutland

The report discusses the influence of inhomogeneous surface conditions on meteorological data from two neighbouring sites in Jutland.

The difference in the averages of the wind speed at the two stations is attributed to dissimilarities in roughness in the area and is described by the use of similarity laws for the neutral planetary boundary layers and for the neutral surface boundary layer.

In contrast, the difference in the averages of the wind direction is attributed to both momentum balance requirements with changing topographical height, and the differential heating and/or cooling within the area.

Authors: (7,53)

3.1.2. Experimental and theoretical investigations of flow over low relief topography

Observations of surface-layer wind profiles over a ramp-like escarpment were compared with the Jackson and Hunt (Q.J.Roy. Met.Soc., 101, 929) analytic theory. In agreement with earlier claims, the maximum perturbations agree with the theory, but it was found that the vertical and downwind variations do not agree as well. This conclusion is supported by previously published wind tunnel results. We believe that this deficiency of the Jackson and Hunt model is caused by the poor turbulence closure used, in which advection and divergence of turbulence transport are neglected. Such terms generally have a smoothing effect on the field and also introduce a measure of sluggishness in the flow response. Another deficiency in the Jackson and Hunt theory has recently been revealed through the preliminary results from the "Askervein" experiment (for further details see Risø-R-461 and 483), where the "inner-layer" depth showed up to be quite a lot more shallow than $\ell n(\ell/z_o) \simeq L/\ell$. However, alternative arguments, based on the balance which must exist close to the ground, between the topography induced horizontal pressure gradient and the vertical stress gradient was discovered to lead to $(\ell n(\ell/z_o))^2 \simeq L/\ell$. In this connection a general scrutiny of the assumptions and hypotheses of the Jackson and Hunt paper and another recent paper on matched asymptotic solutions to the boundary layer flow over topography was made. Some contradictions were found but the result of these findings has not yet been published.

Authors: (5,35)

3.1.3. A boundary layer formulation for atmospheric models

A simple model for the atmospheric boundary layer has been developed for use in operational global weather prediction models and other models where simplicity is required. The model consists of similarity representation of surface fluxes and formulation of turbulent diffusivities above the surface layer based on bulk similarity considerations and matching conditions at the top of the surface layer. The boundary layer depth is represented in terms of a modified bulk Richardson number. Attention is devoted to the interrelationship between predicted boundary layer growth, the turbulent diffusivity, "countergradient" heat flux and truncation errors. The model is especially suited for use in models where some resolution is possible within the boundary layer, but where the resolution is still insufficient for resolving the detailed boundary layer structure.

The model is coupled to a two-layer model of soil hydrology and expression for transpiration. Potential surface evaporation is determined from a stability-dependent Penman relationship; surface heat flux is computed from a surface energy balance.

Authors: (11,62)

3.1.4. Parameterization of boundary layer processes in a spectral general circulation model

A parameterization scheme for planetary boundary layer processes in a general circulation model without any explicit resolution in the boundary layer has been developed. The scheme is unique in the sense that it takes into account the effect of baroclinity in the boundary layer. The scheme has been tested in a one dimensional model with a simplified heat balance at the surface.

A theoretical model of the baroclinic boundary layer has also been developed.

Author: (13)

3.1.5. Inertial-dissipation methods and turbulent fluxes at the air-ocean interface

The use of high frequency atmospheric turbulence properties (inertial subrange spectra, structure functions or dissipation rates) to infer surface fluxes is more practical for most ocean going platforms than direct covariance measurements. The relationships required to deduce the fluxes from such data are examined in detail and several ambiguities are identified. It is noted that over water data or water vapor properties are extremely scarce and the influence of sea spray is completely unknown. It is suggested that conclusive resolution of these questions and a clear establishment of the credibility of the high frequency method would provide a powerful tool to air-sea interaction researchers.

Authors: (7,47)

3.1.6. Spectral structure of turbulence in the stable atmospheric boundary layer

The hydrodynamical equations of turbulence are transformed into a master equation for the velocity distribution function. A group-scaling is introduced for the closure. The spectral balance for the velocity fluctuations of individual components shows that the scaled pressure-strain correlation and the cascade-transfer are two transport functions that play the most important roles. We derive this correlation and find a power spectrum k^{-3} for the horizontal components, while the spectrum for the vertical component drops rapidly by going to the large scales.

Authors: (7,9,69,30)

3.1.7. Clump effect in stably stratified turbulence

Theoretical as well as observational, evidence of a k^{-3} velocity power spectrum exists in a subrange, when the atmosphere becomes very stably stratified. Evidence of a k^{-3} subrange is also found in connection with large scale enstrophy cascade in the troposphere, as well as in the driftwave turbulence in the ionospheric magneto plasma.

Calculations of the turbulent diffusion of a small cloud of particles for such a subrange have been carried out based on a generalization of the classical Brownian diffusion concept. Initially, the cloud diffuses in a stage influenced by the initial size of the cloud. Then it enters a stage of rapid exponential growth and finally a stage of uncorrelated classical Brownian diffusion. Compared to classical diffusion, the effective diffusion coefficient of the cloud is found to be reduced by orders of magnitude for rather long times, thereby exhibiting a socalled clump effect.

Authors: (9,12,7,69,64,34,86)

3.1.8. Modelling velocity spectra in the lower part of the planetary boundary layer

Principles used when constructing models for velocity spectra are reviewed. Based on data from the Kansas and Minnesota experiments simple one-peaked models are set up for the w-spectrum for all stabilities and for u, v and w-spectra for stable conditions. The low-frequency behaviour of the u- and v-spectra for stable conditions are found to be proportional to the Brunt-Väisälä frequency squared and behave as the wavenumber to the power of minus 3.

Authors: (4,7,67)

3.1.9. Dispersion conditions over land and water in a coastal zone revealed by measurements at two meteorological masts

Dispersion conditions are related to the roughness length, z_o, and the Monin-Obukhov length, L. This is done by relating Pasquill's σ_z-curves to the corresponding values obtained by use of a K-model for a continuous ground level source (Gryning et al., 1983). Based on data from two meteorological masts (one at the shore line and one 1 km inland), the model is used to discuss the behaviour of dispersion meteorological statistics over land and water and over land as function of the distance to the coast.

Authors: (2,7)

3.1.10. Progress with the Risø puff diffusion model

Progress has been made with the Risø puff dispersion model developed for risk and safety assessment in connection with nuclear installations. Comparison was made with measurements from an experimental validation study, where the puff model was used to simulate smoke plume observations over homogeneous terrain. The puff model was also proven capable of simulating measured ground level concentrations obtained from elevated tracer release experiments carried out at the Karlsruhe Nuclear Research Center in Germany.

Authors: (9,7,78,83)

3.1.11. Instantaneous observations of plume dispersion in the surface layer

In many transformation and removal processes encountered in the atmosphere, instantaneous rather than time averaged concentrations are of interest. Determination of the instantaneous concentration requires knowledge of the dispersion of the cloud about its center of mass rather than with respect to a fixed coordinate system.

During a recent series of experiments held over homogeneous terrain in Denmark, the relative dispersion of surface released smoke plumes was calculated from aerial photographs. Simultaneously, wind data were obtained from a horizontal array of tower mounted sonic anemometers. This provided information about the spatial and the temporal variability of the dispersing wind field.

The wind data were used to compare commonly used relative dispersion models with the experimental results. A recently proposed statistical model based on the space-time variability of the turbulence field was found to agree with the experimental data over the limited scale considered.

Authors: (9,12,34,70)

3.1.12. Relative diffusion and the underlying turbulence structure

Analytical solutions for the crosswind relative diffusion of a one-dimensional Gaussian puff are obtained by combining a differential equation for the rate of growth of a Gaussian puff with a simple cross covariance model. The cross covariance model is applicable to horizontally isotropic turbulence in the inertial subrange. If one assumes that the turbulence characteristics are constant with time (following the puff), the resulting analytical solution agrees with dimensional arguments for "intermediate" diffusion times, where the puff experiences an accelerated growth. When the turbulence characteristics vary with time as they would for a surface release (in neutral conditions), the solution predicts a linear growth of the puff with time. The latter solution seems to qualitatively agree with surface-source data from the BOREX experiments held in Denmark.

Author: (12)

3.1.13. Tracer experiment in the Øresund-region*

A mesoscale tracer experiment was carried out in the Øresund-region (a land-water-land area). In the experiment a tracer was released from a meteorological mast on the coast of Skåne in southern Sweden. After having travelled about 21 km over the Øresund water surface, the plume encountered the coast of Denmark. Tracer samples were taken at two crosswind arcs, one along the Danish coast and one about 3.5 km inland. During the experiment the atmosphere in the lowest hundred meters was neutral or weakly stably stratified.

The experiment was simulated with a second-order closure dispersion model. Very good agreement with the experimental results was obtained. Simulations were also caried out with the classical Gaussian plume formula, using various schemes for σ_y and σ_z. These models underpredict the measured maximum concentrations by a factor of approximately 2.

* Work supported by Studsvik Energiteknik AB, Sweden.

Authors: (2,61,85,46)

3.1.14. Dispersion from a continuous ground-level source investgated by a K model

A crosswind-integrated K model with wind profiles and K profiles described by Monin-Obukhov similarity relations is solved numerically for the case of the release of a passive substance from a point source at ground level. An extensive analysis is undertaken to compare the numerical model results with experimental results from the Prairie Grass dispersion experiments. Simulations of these experiments are carried out with and without deposition. It is shown that the numerical solution of the diffusion equation yields a good approximation to both the vertical concentration profile and the crosswind-integrated ground-level concentrations when consideration is given to the effect of deposition of the tracer. Despite considerable scatter, the measurements are seen to support the use of the eddy diffusivity of heat rather than the modified expression of that of momentum.

Authors: (2,7,80)

3.1.15. A tracer investigation of the atmospheric dispersion in the Dyrnæs valley, Greenland*

Mining at Kvanefjeld, Greenland, will result in releases of air polluting gases. In order to measure the dilution of these gases tracer experiments were carried out in July-August 1981. It was observed that the flow direction in the valley shifts between downvalley and upvalley with a period of approximately 1 hour. It is suggested that this behaviour is caused by the interplay of a drainage flow and gravity waves. The Kvanefjeld constitutes the northwestern side of a valley. The tracer was released at the Kvanefjeld during the night and sampled in the valley. The measured tracer concentrations were compared with those calculated by use of a conventional model of the dispersion of plumes. The dilution of the tracer was found to correspond to the dilution at ground level of a plume from a stack of 100-200 m height in atmospheric neutral conditions.

* Work supported by the Uranium Project, Risø National Laboratory

Authors: (2,7,61)

3.1.16. Dry deposition of fine particles to city surfaces*

A literature study has revealed that very little data exist for dry deposition of fine particles to city surfaces. Dry deposition to a typical large city, however, with its relatively smooth surfaces of concrete tile and asphalt, would very likely be less than to a vegetated fibrous surface. In an investigation of the deposition velocity of caesium-137 to building surfaces, Roed (Atmosph. Env., 17, 663) finds small values indeed. In making reference to model studies there certainly seems to be an effect. However, it is not at all clear how to extrapolate to full scale, i.e., what scaling factors to use. Presumably they would be combinations of physical parameters, such as: aerosol size, d; surface roughness, z_o; and turbulence, u_*. The present study suggest a deposition velocity $v_d \propto (u_*/z_o)^{1/2} d^{-1}$ with the proportionality factor of the order of 10^{-10} $m^2 s^{-1/2}$ Some experimental work on deposition in cities has been done in the past. However, it has mostly been done in terms of uptake on vegetation or by means of funnel collection. The reason for such studies to be difficult to interpret is not only due to the mix of dry and wet deposition but also due to the general unrepresentativeness of collection agent (i.e., non typical spots in the general surroundings). An experimental outline using aircraft measurements of artificial particle and passive (SF_6) dual tracers has been outlined.

* Work supported by "Nordisk Ministerråd" under the so-called MIL-4 project.

Authors: (5,75,50,73)

3.1.17. Experimental investigation of the effect of obstacles on the dispersion of a heavy gas plume

In the assessment of potential hazards from inadvertent releases of e.g. chlorine, a number of uncertainties exists. One is the effect of obstacles. In this regard a project has been initiated, in which the obstruction used is a usual shelter fence placed perpendicular to the plume axis. The advantage of starting out with an obstacle of this type is that its aerodynamic characteristics are well documented. The model gas used is CO_2. It is released through blow-down from ~ 65 bar through the shortest possible pipe (in the tank, the pipe is submerged in the liquid phase). The diameter of the pipe is 13.7 mm and the discharge is about 2.9 kg/s. In the tests which have been conducted until now, the fence has been positioned 50 m downwind of the release point, and the sampling has been done a further 5 m downwind. The surface of the test area consists of mowed grass. Sampling is done in 25 points separated in the cross wind direction and in the vertical direction as well. The fence is 1.5 m high and 30 m long, and the porosity is about 50%. The sampling units consist of a small centrifugal blower with the outlet choked, and a 50 liter plastic bag. The pump fills the bag in about 2 min., which then determines the typical duration of a release. The bags are analyzed for CO_2 content on a gas chromatograph (COW-MAC 552, with porepack column, helium carrier gas, and hot-wire detector). Typical concentrations (volume/ volume) are of the order of 1%.

Author: (5)

3.1.18. Evaporation from boiling pools of spreading cryogenic liquid

Various industrial gases are stored in liquified form, either under high pressure or refrigerated. Loss of containment in the latter case is a relatively gentle event, the main result being release of cold vapours (at boiling point, 1 atm) as a result of contact between the surface and the cryogenic liquid. In limiting ourselves to cases in which the liquid is boiling, as this involves a simple relationship between the amount of vapour production and the magnitude of the heat flow from the ground we have made a theoretical investigation of the vapour release rate from such a case. This can be found by solving the heat-conduction equation using the boundary condition that the surface temperature instantaneously decreases by the amount ΔT, the temperature difference between the ground and the cryogenic liquid. As we have restricted ourselves to cases where the liquid boils, ΔT is a constant. The solution to this problem is sometimes called Stokes' 1st problem, but in this case, however, the simultaneous growth of pool area due to gravity spreading of the liquid, which prevent infinite boil-off rate at zero time has to be taken into account. We have thereby demonstrated that the expected variation with time of the rate of evaporation from spills (continuous or instantaneous) of cryogenic liquids is a smooth function which starts from zero at $t = 0$, reaches a maximum at a characteristic time t_d, and then follows the classical $t^{-1/2}$ relationship.

Author: (5)

3.1.19. A study of the weather record from Fanø (1872-1980) including an analysis of climate variation*

A study of the weather record from 1872 to 1980 from the island of Fanø, on the west coast of Jutland in Denmark, supports the findings of earlier studies which indicate that the 1930's and 1940's were, climatologically, warmer than the preceeding 50 years and since about 1950. Although the annual precipitation increased up until about 1920 and remains relatively constant since, there was a maximum in shower activity, a minimum in the annual number of cyclone passages, and a maximum in the length of dry episodes in the 1930's and 1940's. There was also a climatological maximum in the severity of the winters during that period.

The climatological trends are clearly, indicated in the data, when averaged over 30 years or so, and the trends in several different climate variables determined from independent measures of the weather at Fanø are consistent with each other.

*Supported by CEC under contract No. CLI-049-DK(G).

Authors: (28,7)

3.1.20. Nibe measurements, contract with DEFU

The measurements at Nibe have continued this year with a final intensive measurement programme on the turbines in their present form. Following the end of these measurements portions of the turbines have been redesigned, new (wooden) blades will be mounted on the B-turbine in January and the A-turbine needs major repairs on the gearbox. Measurements on the changed turbines will continue in 1984 but at a somewhat reduced level.

Authors: (4,1,8,3,9,65,68,52)

3.1.21. Nibe wake, contract with CEGB, U.K

The purpose of this project is to make detailed measurements in the turbulent wake of the Nibe wind turbines. Simultaneous measurements of turbulence and structural response will yield valuable information necessary for the design of arrays of large wind turbines and resolve the discrepancies that exist between numerical models and wind tunnel simulations.

Three instrumented 64 m masts have been erected at Nibe to supplement the existing mast, and the data-logging system has been extended accordingly with respect to both hardware and software. Preliminary measurements have been performed, but the actual measurement programme awaits approval of further funding from the EEC. The total funding for 1983 amounted to 87000 £ of which the major part came from the EEC.

Authors: (4,3,9,76,81,51)

3.1.22. Dynamic loading of wind turbine structures; fatigue life evaluation

Prior to 1983 a model of a horizontal wind turbine rotor had been developed. The model included modelling of the rotor structure and the external loads on the blades. The model is unique compared to other models explicitly made for the purpose of predicting response of the structural components in several ways. It comprises a method to deal with the combined, simultaneous action of periodic and stochastic loads, a realistic model of the atmospheric turbulence and a fatigue model, which is designed for this specific problem.

The model has been finalized and reported during the course of the year and is considered operational, at least for a restricted group of wind turbine types. The immediate task will be to test the validity of the results from the computer code developed on basis of the model, ROTORDYNE. Therefore, it has been planned to carry out test calculation on small, medium and large scale wind turbines and perform a comparison analysis with measurements available.

The project is continued in 1984 where certain refinements and some amendments will be made in order to make the model useful to a broader spectrum of problems.

Authors: (1,8,3)

3.1.23. Preparation of a code for loads and safety of wind turbines

A serious problem for the manufacturers of smaller wind turbines is the uncertainty or the lack of knowledge of the loadings for which the load carrying structure of a wind turbine must be designed. The difficulties in establishing a set of design loads are due to several factors such as the variety of load situations during the life time, the load's dependency of design and operation strategy and the need for including both extreme loads and fatigue causing dynamic loads in the design calculation.

The aim of the project is to provide the wind turbine manufacturer with a set of design loads or a set of simple rules for calculating the loads. The loads combined with a suitable set of partial coefficients should in connection with the Danish structural codes enable a professional engineer to design a wind turbine with sufficient structural strength. The formal code writing is left to a committee under Dansk Ingeniørforening, which has been responsible for other Danish technical codes. The committee, which comprises professional members from the industry, the university and Risø, furthermore supervises the project which consists of collecting and developing the technical content of the code as well as the preparation of the document.

Authors: (1,8)

3.1.24. Development of the utilization of wind energy in Cap Verde

A development project concerning the utilization of wind energy on the Cap Verde Islands west of Senegal was started May 1982, the project being financed by Danida, but executed by the United Nations Development Programme. Risø has been appointed consultant to the project, which primarily aims at the installation of wind turbines for electricity production and at the same time to implement a general training programme for engineers and technicians concerning wind energy.

By the end of 1983, two engineers and two technicians have been guests at Risø for longer or shorter periods to participate in various activities with relevance to wind energy, two wind turbines of each 55 kW have been purchased and tested at Risø (await shipment) and Risø staff have made several travels to Cap Verde in order to carry out site evaluations and plan the activities in collaboration with the Cap Verde counterpart. The first two turbines are expected to be installed in the capital Praia in the first half of 1984.

Authors: (1,3,8)

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3.3. Publications and educational activities

3.3.1. Publications

ECKMAN, R.M. Relative diffusion and the underlying turbulence structure. Risø-M-2412, 50 pp.

ENGER, L., GRYNING, S.-E., LYCK, E., and WIDEMO, U. (1983). Simulations of a tracer experiment in the Øresund region. In: Preprints of the 14th International Technical Meeting on Air Pollution Modelling and Its Application, Copenhagen, September 27-30, p. 2,1-2,15.

GRYNING, S.-E. and LYCK, E. (1983). A tracer investigation of the atmospheric dispersion in the Dyrnæs valley, Greenland. Risø-R-481, pp. 67.

GRYNING, S.-E., van ULDEN, A.P., and LARSEN, S.E. (1983). Dispersion from a continuous ground-level source investigated by a K-model. Quart. J.R. Met. Soc. Vol. 109, 355-364.

GRYNING, S.-E., LYCK, E., ENGER, L., and WIDEMO, U. (1983). Sporstofforsøg i Øresundsområdet. Vejret, 4.

GRYNING, S.-E. and LYCK, E. (1983). Some observations of the nighttime flow-field in the Dyrnæs-valley, Greenland. Proceedings from "13. Nordiske Meteorologmøde", Copenhagen 7-11 June 1982, Vol. 1, 199-211.

GRYNING, S.-E., LYCK, E., and WIDEMO, U. (1983). A tracer investigation of the atmospheric dispersion in the Øresund Region. Data and technical report. Studsvik Report, Studsvik-83/4, pp. 52.

HEDEGAARD, K. and LARSEN, S.E. (1983). Wind speed and direction changes due to terrain effects revealed by climatological data from two sites i Jutland. Risø-R-434, 120 pp.

JENSEN, N.O. (1983). Escarpment induced flow perturbations, A comparison of measurements and theory. J Wind Eng. and Industrial Aerodynamics, 15, 243-251.

JENSEN, N.O. (1983). Dry deposition of fine particles to city surfaces. In: Preprints of the 14th International Technical Meeting of Air Pollution Modelling and its Application, Copenhagen, September 27-30, p.

JENSEN, N.O. (1983). On cryogenic liquid pool evaporation. J. Hazardous Materials, 3, 157-163.

LARSEN, S.E. and GRYNING, S.-E. (1983). Dispersion conditions over land and water in a costal zone revealed by measurements at two meteorological masts. In: Preprints of the 14th International Technical Meeting on Air Pollution Modelling and Its Application, Copenhagen, September 27-30, p. 2,1-2,14.

LARSEN, S.E., GRYNING, S.-E., and JENSEN, N.O. (1983). Sammenligning af spredningsmeteorologisk statistik fra forskellige steder i Danmark. Proceedings from "13. Nordisk Meteorologmøde", Copenhagen, 7-11 June 1982, Vol. 1, 295-308.

LARSEN, S.E. and JENSEN, N.O. (1983). Summary and interpretation of some Danish climate statistics. Risø-R-399, 76 pp.

LILLY, D.K. and PETERSEN, E.L. (1983). Aircraft measurements of atmospheric kinetic energy spectra. Tellus, Vol. 35A, No. 5, 379-382.

MADSEN, P.H. (1983). Stochastic response analysis and first-passage probabilities. Risø-R-485, 171 pp.

MADSEN, P.H. and KRENK, S. (1983). An integral equation method for the first-passage problem. DCAMM report No. 276, The Technical University of Denmark.

MIKKELSEN, T. (1983). The Borris Field Experiment: Observations of smoke diffusion in the surface layer over homogeneous terrain. Risø-R-479, 86 pp.

MIKKELSEN, T. (1983). A parametric description of a skewed puff in the diabatic surface layer. Proceedings from "13. Nordiske Meterologmøde", Copenhagen, 7-11 June 1982, Vol. No. 1, 309-313.

MIKKELSEN, T. and ECKMAN, R. Instantaneous observations of plume dispersion in the surface layer. In: Preprints of the 14th Int. Technical Meeting on Air Pollution Modelling and its Application, Copenhagen, September 27-30, p.

PETERSON, E.W. (1983). A study of the weather record from Fanø (1872-1980) including an analysis of climate variation. Risø-R-493, 70 pp.

PETERSON, E.W. and LARSEN, S.E. (1983). Klimatiske ændringer over det sidste hundrede år ved Fanø (Climatic changes over the past 100 years at Fanø). Vejret 3, 18-20.

PÉCSELI, H.L., MIKKELSEN, T. and LARSEN, S.E. (1983). Drift wave turbulence in low-β plasmas. Plasma Physics, 25, 1173-1197.

WOETMANN NIELSEN, N., JENSEN, G., and CHRISTENSEN, O. (1983). Stormen 24 November 1981. Vejret Vol. 5 No. 1, 27-40.

WOETMANN NIELSEN. (1983). Vejr og torden. Lecture notes: DIEU, Technical University of Copenhagen, 11 pp.

3.3.2. Contract reports

FRANDSEN, S., HANSEN, J.C., and MADSEN. P.H. Utilization of wind energy for electricity production in the Cape Verde Islands, Progress report (January, May, September), (not public), 721 pp.

HØJSTRUP, J. (1983). Nibe Wake part one. Contract report to CEGB, November 65 pp.

JENSEN, N.O. (1983). Notat vedrørende større systemer for glatførevarsling (systems for detection of icing conditions). Work done under contract to Vejdirektoratet. 30 pp.

JENSEN, N.O., PETERSEN, E.L., and TROEN, I. (1983). Extrapolation of mean wind statistics with special regard to wind energy applications. Prepared for the World Meteorological Organization, 85 pp.

JENSEN, N.O., TROEN, I. (1983). Vurdering af vindklimaet ved færgehavne i Storebælt (Estimation of the wind climate at the ferry ports in the Great Belt). Work done under contract to the Danish Railroad Authority (DSB).

LARSEN, S.E. (1983). Pladsansøgning, Stevns Syd. Risø-I-132, 181 pp.

LARSEN, S.E. (1983). Pladsansøgning Gylling Næs. Risø-I-143, 193 pp.

MADSEN, P.H., FRANDSEN, S., HOLLEY, W.E., and HANSEN, J.C. (1983). Dynamic analysis of wind turbine rotors for lifetime prediction. Work done under contract to the Danish Ministry of Energy and DEFU, 201 pp.

PETERSEN, E.L. (1983). Climate application referral system/wind energy. World Climate Application Programme, WMO-56.

3.3.3. Conference contributions

GRYNING, S.E. and JENSEN, N.O. Dry deposition of fine particles to city surfaces. 14th International Technical Meeting on Air Pollution Modelling and its Application. Copenhagen, Denmark, September 27-30.

GRYNING, S.-E. and LARSEN, S. Dispersion conditions over land and water in a coastal zone revealed by measurements at two meteorological masts. 14th International Technical Meeting on Air Pollution Modelling and Its Application, Copenhagen, September 27-30.

HAUGE MADSEN, P. and BARBOSA, A. (1983). Utilization of wind energy in the Cape Verde Islands. Conf. C32, Rural Power Sources, UK-ISES, Newcastle, U.K., March 29-39.

JENSEN, N.O. Escarpment induced flow perturbations, A comparison of measurements and theory Sixth International Conference on Wind Engineering, Auckland, New Zealand, April 6-7.

JENSEN, N.O. Economy and performance of typical, commercially available, Danish wind turbines. Sixth International Conference on Wind Engineering, Auckland, New Zealand, April 6-7.

JENSEN, N.O. En teoretisk undersøgelse af om det er nødvendigt at tage hensyn til at typiske tunggas-udslip også ofte er kolde (On the necessity of taking into account that a heavy gas release might be cold). NORDFORSK seminar, Umeå, Sweden, August 16-18.

JENSEN, N.O. Experimentel undersøgelse af todimensionale forhindringers indflydelse på spredningen af en tung gasplume. (Experimental investigation of the effect of a two dimensional obstacle on the dispersion of a heavy gas plume). NORDFORSK seminar, Umeå, Sweden, August 16-18.

JENSEN, N.O. Nuværende og planlagte aktiviteter på Risø i forbindelse med dannelse, og videre spredning af tunge gasser. (Ongoing and planned activities at Risø in relation to the formation and subsequent dispersion of heavy gases). NORDFORSK Seminar, Umeå, Sweden, August 16-18.

JENSEN, N.O. On the dilution of a dense gas plume: Investigation of the effect of surface mounted obstacles. IUTAM Symposium "Atmospheric Dispersion of Heavy Gases and Small Particles", Delft, The Netherlands, August 29 - September 2.

LARSEN, S.E., OLESEN, H.R. and HØJSTRUP, J. Parameterization of the low frequency part of spectra of horizontal velocity components in the stable surface boundary layer. Conference on Models of Turbulence and Diffusion in Stably Stratified Regions of the Environment, Cambridge, March 15-16.

MADSEN, P.H. (1983). Dynamic analysis of wind turbine rotors for life time prediction. Structural design criteria for LS WECS, IEA LS WECS expert meeting, Greenford, Middlesex, March 7-8.

MIKKELSEN, T. and PECSELI, H.L. Diffusion of a cluster of particles in a turbulent plasma. 18th Nordic Symposium on Plasma and Gas Discharge Physics, Geilo, Norway, Feb. 12-17.

MIKKELSEN, T. and THYKIER-NIELSEN, S. Description of the Risø puff diffusion model. In seminar on: Emergency Preparedness: Real time diffusion models, Rome, June 27-28.

MIKKELSEN, T. and ECKMAN, R. Instantanecus observations of plume dispersion in the surface layer. 14th Int. Technical Meeting on Air Pollution Modelling and its Application. Copenhagen, Denmark, September 27-30.

PETERSON, E.W. and LARSEN, S.E. Climatic variation in Northern Europe during the past century. Evidence from a Danish record. The second Nordic Symposium on Climate Changes and Related Problems, Stockholm, May 16-20.

TROEN, I. and PETERSEN, E.L. The application of climatological data to determine the wind climate of a non-mountaineous region. II International Meeting on Statistical Climatology, Lisboa, Portugal, September 26-30.

3.3.4. Lectures

GRYNING, S.E. A tracer investigation of the atmospheric dispersion in the Øresund-Region. NORDFORSK meeting, Helsingborg, Sweden, (January).

GRYNING, S.E. Atmospheric dispersion investigated by tracer experiments. Meteorologisk modelling av närzonen vid et kärnkrafthaveri, Rådet for Kärnkraftsäkerhet. Stockholm, Sweden, (March).

GRYNING, S.E. Dispersion from a ground-level source investigated by a K-model. Uppsala University, Sweden (March).

GRYNING, S.E. The flow-field in the Dyrnæs Valley, Greenland. Presentation at Nordisk forskarkurs i Mesometeorologi, Pinnarps, Sweden (May-June).

GRYNING, S.E. Elevated source tracer experiments in the Copenhagen area. Amtswehr für Geophysics, Traben Traback, F.R.G. (August).

GRYNING, S.E. The Øresund-project. EEC-meeting at Kernforschungszentrum Karlsruhe, Karlsruhe, F.R.G. (October).

GRYNING, S.E. Elevated source tracer experiments in the Copenhagen area. Bilateral workshop, Risø-KfK, Karlsruhe, F.R.G. (November).

GRYNING, S.E. The flow-field and dispersion in the Dyrnæs Valley, Greenland. Eidgenössisches Institut für Reaktorforschung, Würenlingen, Switzerland (December).

JENSEN, N.O. Spectral coherence in turbulence. Canberra Fluid Mech. Seminar, Australian National University and CSIRO Division of Environmental Mechanics, Australia (April).

JENSEN, N.O. On the calculus of heavy gas dispersion. Division of Environmental Mechanics CSIRO, Canberra, Australia (April).

JENSEN, N.O. Studies of sea/land wind adjustment. University of Hannover, F.R.G. (June).

JENSEN, N.O. Deposition of fine particles to cities. Bilateral workshop, Risø-KfK, Karlsruhe, F.R.G. (November).

LARSEN, S.E. Current and planned experimental activities at Risø. British Meteorological Office, Bracknell, U.K. (March).

LARSEN, S.E. Climate research at Risø. Université Catholique de Louvain, Louvain-La-Neuve, Belgium (February).

LARSEN, S.E. Work on atmospheric dispersion at Risø. Bilateral Workshop, Risø-KfK, Karlsruhe, F.R.G. (November).

MADSEN, P.H. Stokastisk respons og første-passage sandsynligheder. The Technical University of Denmark (April).

MADSEN, P.H. The first-passage problem, an integral equation approach. Oregon State University, U.S.A. (November).

MADSEN, P.H. Wind turbine extreme loads and fatigue damage. Oregon State University, U.S.A. (November).

MADSEN, P.H. Lifetime prediction of wind turbine rotors. Rocky Flats Test Center, Colorado, U.S.A. (November).

MIKKELSEN, T. Analyse og fortolkning af stokastiske tidsserier fra micrometeorologiske feltmålinger. The Technical University of Denmark, Copenhagen (May).

MIKKELSEN, T. Formulation and experimental evaluation of an operational puff diffusion model. The Technical University of Denmark, Copenhagen (June).

MIKKELSEN, T. Modeludvikling i Norden. In seminar on: Meteorologisk modellering af nærzonen ved et kernekrafthaveri. Rådet for Kernekraftsikkerhed, Stockholm, Sweden (March).

MIKKELSEN, T. Risø's puff-model, meteorologi og spredning. SNODAS-meeting, Lillestrøm, Norway (October).

MIKKELSEN, T. and THYKIER-NIELSEN, S. Risø's puff-diffusion model for risk and safety assessment. Bilateral workshop, KfK-Risø, Karlsruhe, F.R.G. (November).

MIKKELSEN, T. Atmosfærisk spredning og puff modellering. Forsvarets Forskningsanstalt (FOA4), Umeå, Sweden (December).

PETERSEN, E.L. Status of the European Windatlas Contractors meeting, Bruxelles, Belgium (February).

PETERSEN, E.L. Meteorological research at Risø. Institut d'Astronomie et de geophysique. Université Catholoque de Louvain, Louvain-la-Neuve, Belgium (February).

PETERSEN, E.L. The European and the Danish Windatlas. The Danish Meteorological Society, Copenhagen (April).

TROEN, I. Sea breeze modelling, Oregon State University, U.S.A. (January).

TROEN, I. A variational method in dispersion theory. Naval Postgraduate School, Monterey, California, U.S.A. (March).

TROEN, I. A variational method in dispersion theory. Oregon State University, U.S.A. (May).

WOETMANN NIELSEN, N. Lavtryk på synoptisk og subsynoptisk skala. The Danish Meteorological Society, Copenhagen (February).

WOETMANN NIELSEN, N. Vejr og torden. DIEU, Technical University of Denmark, Lyngby (November).

WOETMANN NIELSEN, N. Det barokline grænselag og klimamodeller. Institute of theoretical Meteorology, University of Copenhagen, (November).

WOETMANN NIELSEN, N. Om polare klimavariationer og deres mulige forudsigelse. The Danish Meteorological Society, Copenhagen, (December).

4. TEST STATION FOR SMALL WINDMILLS

4.1. Introduction

The test station is operated as a part of the meteorology section, mainly financed by the ministry of energy (energy research programme and subsidy for renewable energy programmes). It is responsible for the testing and licensing of windmills for the Danish market. At the same time the test station offers consultative assistance for the Danish windmill manufacturers, and it undertakes R & D on the broad field of windmill design, operation and application.
During 1983 five windmills went through standard tests, one microprocessor control unit and some airbrakes went through reduced standard tests. Intensive test of a new rotor of larger diameter for a 55 kW machine was carried out to check the performance of the rotor and to study the increased loads due to the larger rotor. A new set of licensing criteria is being developed. Three new general licenses and six prototype licenses were given. A catalogue of Nordic wind mills was worked out. Work on the problems of a Wind/Diesel combination was started. In several cases intensive consultative assistance on windmill technology was given to the ministry of energy and to Energistyrelsen.

4.1.1. Standard measurements

As a part of the licensing function and of the energy recearch programme, windmills are tested on a routine basis using the standard measurements programme. The program is still developping and new points has been involved such as loads on blades in the flapwise direction, no load transmission power, and frequency spectra for different signals.
During 1983 three windmills have finished the test, all of them after adjustments or modifications. Furthermore components as a rotor and a control unit were tested on an existing windmill.
The dominating problems are still the prediction of power regulation by aerodynamic stall and the function of airbrakes. The theoritical models are used to calculate comparative values to the measured results, in order to adjust the models and to advise the manufacturer.
Three reports were published.

Authors: (10)

4.1.2. Measurements on the DWT 265 kW windmill at Koldby, Jutland

As a part of the research and development program of the Test Station for Small Windmills, field measurements on the DWT 265 kW windmill at Koldby in Jutland have been performed during the summer of 1983. The windmill was instrumented with twenty-nine sensors, of which thirteen were strain-gauges mounted on tower and rotorstays of the windmill. Seven sensors were mounted on a meteorological mast two rotordiameters away from the windmill, and the rest of the sensors were mounted on the nacelle for measurements of the actual condition of the windmill. The measurement program was divided into three parts. The first part was dealing with standard measurements according to the Test Station standard test program. The second part involved all the sensors at the rotor, and using a high sampling rate the rotor loads were measured for different operating conditions. The third part involved all the sensors, and the measurements were performed at a high sampling rate. These measurements were performed to give a picture of the total loads on the structure, including interference between different parts of the windmill.

Autnors: (2)

4.1.3. Aerodynamic and structural performance of a new LM-8.6 m blade

A VESTAS 15 windmill was equipped with a new rotor manufactured by LM with a diameter of 17.2 m instead of the usual 15.4 m rotor. Apart from this, the system was not modified. One aim was to investigate the aerodynamic behavior of the rotor. Another was the structural response of the windmill when exposed to the loads of the somewhat larger rotor.
The blade tip angle was varied and the optimum in relation to efficiency and stall-characteristic was found. Blade and rotor loads as a function of windspeed, yaw angle and blade position was measured as well as the drag coefficient at 90° angle of attack. From this the blade profile data were estimated.
Variation of the blade profile data was performed by mounting "turbotape" (roughness increasing surface) at different percentage chords at the upperside of the profile. Placing, roughness and Reynolds Number effects were investigated and interesting results extracted.
Accelerations of the nacelle as well as blade root bending moments were measured. The different spectra and transfer functions were determined in a search for possible dynamic problems introduced by using the large rotor. No serious problems were observed. The calculated annual energy output of the windmill would be increased app. 30% by using this rotor on an average site (roughness class 1-2) in Denmark.

Authors: (9)

4.1.4. Licensing of windmills

The test station is responsible for licensing windmills. The license gives the possibility for obtaining subsidy from the state when raising a windmill.
In practise much attention is given to this approval from authorities and customers both here and abroad. Nearly all windmills sold in Denmark or exported are approved.
New and more detailed rules for approving windmills have been worked out. They mostly serve as a frame for this work and show only general demands. This is because the knowledge about windmills is increasing rapidly and continuously must be taken in to account in the specific demands to windmills. Two types of licenses are given:
To prototypes, which only allows to obtain subsidy to one windmill.
General license allows subsidy to all windmills with the approved specifications. This license is given for one year.
At the end of 1983 13 types of windmills have general licenses. 3 of these were given for the first time this year. 6 licenses were given to prototypes. 12 applications for license are under reading. 11 licenses valid at the start of the year have not been renewed.
Most of the approved types have been more or less changed during the year. These changes have been approved continuously.

Authors: (6)

4.1.5. Measurements on two windmills to Cape Verde

Two 55 kW Vestas windmills will be erected in the republic of Cape Verde as a part of a program financed by the UNDP.
These two windmills were operating on Risø July-october and went through a standard measurement program.
At the same time this gave the possibility to compare two windmills built according to the same specifications. Only minor differences were found.
Special attention was given to heat in the generators because of the warm site in Cap Verde. It was decided to change the generators to generators with a higher class of insulation.

Authors: (6)

4.1.6. An experiment with telecommunication (TEEO)

The test station is involved in a project called TEEO, directed by the Directorate of Telecommunication.
As a experiment a data base is established in Risø's computer. Manufacturers, consulting firms and others are connected to this data base via terminals.
Some programs for calculation on windmills, a program for calculating the power production at a given site and a statistical program for manipulating and running the data base. This in itself contains performance data on a monthly basis for about 350 windmills.
If the experiment shows a demand, the data base can be extended with many more programs and facilities.

Authors: (6)

4.1.7. Test benches

When reviewing windmills and planning research the need for specialized test benches quickly gets obvious.
A test stand for testing the strength of windmill blades to static loads has been build. On this stand the response to a static load of 300 N/m^2 of swept rotor area can be tested for blades op to 10 m length.
Two types of blades has been tested several times and redesigned on the basis of the experience gained. One cast iron hub has been tested and one more is being tested.
In the same test stand the first fatigue testing of a blade has been tried in order to develop a simple testing method.
A test stand for measuring losses and other problems in the power train and especially the gear box is in the beginning. One gearbox is under testing.

Authors: (5)

4.1.8. Research wind turbine

On industrial windmills it is quite often difficult to get access to forces, moments or other parameters, that are needed. The machines are usually constructed for producing efficiently rather than for allowing access to the parameters, that the researcher needs.
Spurred by this problem, the test plant has embarqued on the construction of a machine meant to give access to any parameter, that is of any foreseeable interest in the verification of theoretical models. The machine is furthermore meant to be flexible enough to allow the easy mounting of various components like blades, controls etc., that needs testing, i.e. to be a component-test facility as well.
The machines is meant to carry rotors of diameter up to 15 m. It has a tower height of 15.7 m and a slip-ring inductiongenerator of 30 kW.
The type of research that is anticipated with this machine is for instance: Stall regulation test of new blade designs, air brake studies and complete mappings of loads in the rotor and other parts of structure.
The research wind turbine is a complicated construction and has taken a long time to build up. The turbine will continously be adapted to new purposes.

Authors: (5)

4.1.9. Wind/diesel project

A difficult problem with electricity production from windmills is the stand alone power station. One way of solving the problem is to combine a windmill with a diesel-generator. The Test Station has started a cooperation with Chalmers Täkniska högskola in Göteborg to bring about one solution for a combined wind/diesel power plant. The council of nordic ministers has sponsored the work, which is planned to continue until the end of 1985. The power plant will consist of a normal stall-regulated windmill with an induction generator and a diesel-aggregate with a diesel engine, a clutch, a flywheel and a synchronous generator. The power plant will be simulated in the laboratory with smaller units. The full size power plant will be tested in the laboratory at Chalmers without the windmill, and afterwards the diesel-aggregate will be installed at the Test Station at Risø and be connected to a windmill. The aim of the project is to verify static and dynamic loads during different kind of operating conditions. The economy for this combination of a power plant will also be analysed.

Authors: (2)

4.1.10. Catalog of commercial windmills in the Nordic countries

The market for windmills has developed remarkably fast during the last few years, and the nordic countries, especially Denmark, have reached a strong position on the world market. In 1982 the counsil of Nordic ministers funded the work on a nordic catalog of commercial windmills, and the work was accomplished in 1983. The informations in the catalog are based on data, which the manufacturers supplied from a questionaire sent to them. For each type of windmill one page is used to describe specifications. A photograph shows the windmill, and all main components are mentioned in the description. A second page describes power performance, testirg, license, a production status and a catalog price. Curves are shown for power output, annual mean energy production for different mean wind speeds and for the sound pressure level 50 m´s from the windmill.

Authors: (2)

4.1.11. Future developments of windmills in Denmark

The status of development of small windmills in Denmark and the trends in the future developments has been discussed in a report for the Risø Energy Systems group. An investigation of the development in the major failures of the windmills, in the total price for installation and in the annual energy production demonstrates the rapid development during the last few years. A status is made over the present technology used in the windmills in Denmark. Furthermore some of the possibilities for making the windmills more economical were reviewed. Finally the perspectives for the big windmills in Denmark were studied. The third generation windmill show some scope for competing with coal fired plants.

Authors: (4)

4.1.12. Consultative assistance to Energistyrelsen

The potential energy resources in a small village is described in a report made by Energistyrelsen. One of the resources which are investigated by the test station, is the potential windresources in a small village called Vester Nebel. A report is made describing this work.
In the same program all energy resources are described and the test station for small windmills has made a report about which tasks (economic, technical and wind resources) shall be taken in account when one plans to erect a windmill.
There are plans to build more than 12 windmill parks in Denmark. The ministry of energy gives extraordinary subsidy to a few of the companies or other local authorities. The test station has made the necessary technical and windresources investigation on the windmill park.

Authors: (4)

4.1.13. Commercial activities

In an attempt to broaden the financial basis for the test station programme, an effort is being made to formulate services that can be offered to national and international costumers on engineering review and on standard testing of windmills. The two services are modelled over our ongoing work in connection with the licensing and testing of machines that apply for the danish state subsidy. The main difference from the latter is, that the commercial services only aim at giving a costumer-oriented standard description and evaluation of the machine. It does not as in the state supported work contain consultative assistance on improving the machines being tested.

Authors: (1)

4.2. Participants in the work at the test station for small windmills

Scientific staff

1. Christensen, C.J. (4.1.13)
2. Friis Pedersen, T. (4.1.2, 4.1.9, 4.1.10)
3. Harvøe, P.
4. Hjuler Jensen, P. (4.1.11, 4.1.12)
5. Krogsgaard, J. (4.1.7, 4.1.8)
6. Lading, P. (4.1.4, 4.1.5, 4.1.6)
7. Lundsager, P. (at present at University of Buffalo, U.S.A.)
8. Petersen, H. (consultant)
9. Rasmussen, F. (4.1.3)
10. Rasmussen, P. (4.1.1)

Secretaries

11. Jensen, A.
12. Madsen, J.

Technical staff

13. Hagensen, P.
14. Nørregaard, I.
15. Sørensen, V.
16. Johansen, A.

Guest scientist

17. Holley, B. (now at Oregon State University, Oregon, U.S.A.)

4.3. Publications and educational activities

4.3.1. Publications

FRIIS PEDERSEN, T. (1983). Standard measurements on windmills at the test station for small windmills at Risø, Denmark. Wind Energy Conference, ASME-paper.

FRIIS PEDERSEN, T. (1983). ASME-vindmølle-konference og studietur til U.S.A. Rejserapport.

FRIIS PEDERSEN, T. (1983). Nordisk Vindmøllekatalog.

RASMUSSEN, P. (1983). Blad- og rotorlaster for Vestas 15. Risø-M-2392. 50 pp.

RASMUSSEN, P. (1983). Blade and rotor loads for Vestas 15. Risø-M-2402. 48 pp.

RASMUSSEN, P. (1983). Afprøvning af Kuriant vindmølle type 15/4 K. Risø-M-2385. 48 pp.

RASMUSSEN, P. (1983). Afprøvning af Bonus vindmølle, 55 kW prototype med reduceret omdrejningstal fra Danregn Vindkraft A/S. Risø-M-2400. 36 pp.

RASMUSSEN, P. (1983). Afprøvning af Vestas vindmølle type 15, 55 kW. Risø-M-2403. 36 pp.

Newsletter No. 7 (1983) (In Danish)
Newsletter No. 8 (1983) (In Danish)

3.3.2. Contract reports

HJULER JENSEN, P. (1983). Gennemgang af forskellige forhold der bør tages hensyn til ved anskaffelse af vindmølle.

HJULER JENSEN, P. (1983). Kortlægning af vindenergi i Vester Nebel.

HJULER JENSEN, P. (1983). Notat om vindmølleparker.

HJULER JENSEN, P. (1983). Status og fremtid for vindmøller i Danmark.

HJULER JENSEN, P. (1983). Vindmøller. Teknisk leksikon-revision.

HJULER JENSEN, P. (1983). Pjece om vindmøller udgivet af Kreditforeningen Danmark.

4.3.2. Lectures

CHRISTENSEN, C.J. Recent developments in Danish windmill technology and industry.
1) AWEA wind energy conference and exhibition. San Fransisco, California, U.S.A. (October).
2) Spanish wind energy symposium. Tenerife (November).

CHRISTENSEN, C.J. and PETERSEN, H. The wind energy programme in Denmark and the Test Station for Small Windmills at Risø. U.S.A. test station, Rocky Flats, Boulder, Colorado, U.S.A. (May).

FRIIS PEDERSEN, T. Standard measurements on windmills at the Test Station for Small Windmills at Risø, Denmark. ASME conference, Houston, Texas, U.S.A. (February).

FRIIS PEDERSEN, T. Vindmøller i Danmark og Nordisk Vindmøllekatalog. Konference för småskalig vindenergi, Uppsala, Sweden (April).

FRIIS PEDERSEN, T. Målinger på vindmøller. Eksperimentel Mekanikdag, Risø (October).

FRIIS PEDERSEN, T. Vindkarft i Danmark. Historisk rids, nuværende stade og Risø's arbejde med vindkraft. Vindenergisymposium, Hangö, Finland (November).

HJULER JENSEN, P. Teknisk status over vindmøller. Danske Elværkers Forenings kursus (February).

HJULER JENSEN, P. Generelt om vindmøller. Forelæsning for studerende på Danmarks tekniske Højskole (April).

HJULER JENSEN, P. Vindmølle-forsikringsspørgsmål. Forsikringsingeniører i Danmark (October).

HJULER JENSEN, P. Foredragsrække om vindmøller for kommuneingeniører, Energistyrelsen (December).

LADING, P. Dansk energipolitik og vindkraftens rolle. Vindenergi symposium, Hangö, Finland (November).

LADING, P. Vindmøllers økonomi. Vind-energi symposium, Hangö, Finland (November).

PETERSEN, H. Technical Experience with Wind Energy Utilization in Denmark. Conference ENERGIE´ 83, Hamburg, F.R.G. (April).

PETERSEN, H. Wind Energy Utilization and Technique. Harbin, Beijing and Hangzhou, China (September-October).

PETERSEN, H. Wind Energy Technique in Denmark. Reykjavik, Island (November).

RASMUSSEN, F. Measurements and calculations of blade and rotor loads. Dansk Vindteknisk Selskab.

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